Pneumatic Spirit, P. 21

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*With Lt.-Col. Jeffreys's Compliments.*

A

CONFUTATIVE

# BIOGRAPHICAL NOTICE

OF

# JULIUS JEFFREYS, F.R.S., F.G.S.

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BY

LT.-COLONEL E. JEFFREYS,

BENGAL ARMY.

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London:

LONGMAN & Co., PATERNOSTER ROW.

1855.

# TO THE MEMBERS

OF THE

# ROYAL INSTITUTION OF GREAT BRITAIN.

*In publishing the following Biographical Notice, Lt.-Colonel Jeffreys has had primarily in view its Circulation among the Members of the different Learned Societies with whom his brother is connected, and to whom the moral, as well as scientific reputation of their members, individually, cannot be a matter of indifference.*

*But it is the Members of the Royal Institution whose attention he more particularly requests to the circumstances detailed in p.* 12, *et sequent.*

*He does not doubt that it must be the earnest desire of every Member that the Institution should, as far as possible, be* sacred to truth of all kind. *He does not presume to inquire*

*whether such a lecture as that delivered on the 2nd of March last, can, on account of some points of undoubted value and interest in it, be viewed by the Council as worthy of the Institution, though containing various unsound and even contradictory statements; but he is bound to inquire whence it should happen that a libellous statement, so opposed to truth and so injurious, as that confuted in p. 14, could, not only be put forth from the Theatre, but be afterwards published in the Proceedings, and thereby given the authority and durability of its permanent records; and this with its earlier records, and with a copy of the Patent Office records at hand in the library by which to correct it!*

*Colonel Jeffreys cannot doubt that every member of the Institution to whom this fact shall become known, will desire the error shall be promptly corrected.*

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# CONTENTS.


PAGE

Reasons for this Biographical Notice .......... 3
Mr. Jeffreys's Family and Professional Pursuits .......... 4
Essay on the Mechanism of the Joints and Muscles .......... 4
Letters from Mr. Travers, Sir Astley Cooper, and Mr. Abernethy ... 5
Essay on the Laws governing the Attraction and Repulsion of Molecules.. 5
Landing in Calcutta, treatment of Cholera .......... 6
Tour in the Himalaya, Essay on the climate, formation of sanitary stations.. 6
Surgical Operations .......... 6
Appointed Staff Surgeon of Cawnpore .......... 7
Invention of the Refrigerator .......... 7
Introduction of various arts into India on a large scale .......... 7
Papers on Schools of useful Art .......... 8
Inquiries, and views on Canal Irrigation and Navigation in India, and on Well Irrigation .......... 8&11
Invention of Hydraulic Apparatus and Windmill .......... 8
Papers on Indian improvement and on Roads, &c. .......... 9
Letter from Lord William Bentinck .......... 9
" Lord Metcalfe .......... 10
" Ross D. Mangles, Esq., M.P. .......... 10
Plan for converting the pitching and rolling of ships into a progressive motion .......... 10
Introduction to India Directors and proposal of a Lectureship on the application of science to Indian Art .......... 10
Papers in London Asiatic Journal on "The Resources of India," Irrigation, Canal Navigation, &c. .......... 11
Invention of the Respirator .......... 12
Refutation of attempts to disprove the originality of the invention .......... 12
" of a libellous charge of piracy .......... 14
Invention of machines and processes for making the Respirator .......... 16
Letter from C. Babbage, Esq., F. R. S., on the perfection of the Work...... 17
Gratitude expressed for benefits experienced .......... 17
Refutation of other groundless charges .......... 17
Refutation of mistaken reports as to the lucrative character of the invention 19
Refutation of a false proposition respecting Patents .......... 19
True principle guiding the tenure of patents for remedial instruments...... 20

PAGE

Invention of Pneumatic or Ventilating grate; sketch of ditto ..... 21

Invention of smoke consuming boiler furnace; sketch of ditto ..... 22

Treatise on "The statics of the Human chest, animal heat," &c. ..... 23

Letter from Sir B. Brodie, Bart., F.R.S. ..... 24

" Dr. Watson, F.R.S ..... 24

" Dr. Prout, F.R.S. ..... 25

" Sir H. Holland, Bart., F.R.S. ..... 25

" Dr. Paris, V.P. R.S ..... 26

" Professor Daniell, F.R.S. ..... 26

" Dr. Mayo, F.R.S ..... 26

Temperance and Opium Questions, Labourers' Friend and Needlewomen's Societies ..... 26

Experiment proving the solubility of silica in steam at a white heat ..... 27

Experiment on the exosmosis of liquid and gaseous particles ..... 28

Papers on warmth and ventilation, and on the treatment of the lungs and skin 28

Pamphlets on Teetotalism, on "Dissenters' Chapels' Bill," on the "China War," on "the Main Question for Church Laymen," and on "Loss of Life at Sea, through the inefficiency of ship's boats." ..... 28

Invention of new boat pendants and clearing apparatus ..... 28

Successful trial of ditto in the Gold Finder ..... 28

Letter from Messrs. Jones and Palmer, Liverpool, owners of "The Gold Finder" ..... 28

" " Captain Schomberg, R.N., Liverpool, Government Emigration Agent ..... 29

" " Lieut. Lord, R.N., Marine Surveyor, Liverpool ..... 29

" " Captain Cook, Superintendent of Pilots, Liverpool ..... 29

" " Captain Wm. Mitchell, Surveyor of Underwriters' Association 30

" " Mr. John Crawford, Liverpool ..... 30

Trial of the plan ordered by the Admiralty and deferred.—Many Accidents.—Loss of the "Europa," with Col. Moore and Troops.—Success of the plan in the "Army and Navy" Steamer ..... 30

Invention of the "deflecting and reflecting grate" for curing the domestic smoke of towns; sketches of ditto ..... 30

Proposal of temporary barracks for the Crimea, &c., to be proof against heat, cold, and conflagration ..... 32

Plan for rendering ships of war proof against conflagration, and invention of a new fabric for ships and particular form for Batteries ..... 32

Proposed improvements in ordnance and rifles ..... 37

Various inventions and constructions in machinery and manufacturing processes, and in the refinement of Saltpetre ..... 37

Philosophical observations ..... 37

Learned Societies into which Mr. Jeffreys has been elected ..... 38

Concluding remarks ..... 38

A CONFUTATIVE

# BIOGRAPHICAL NOTICE

OF

# JULIUS JEFFREYS, F.R.S., F.G.S., &c.,

BY

## LT.-COLONEL E. JEFFREYS,

BENGAL ARMY.

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WHILE the reader who shall favor these pages with a perusal, will notice the variety and the importance of the subjects comprised in the labours I have briefly sketched, and may find many interesting points of inquiry suggested, I beg to explain that the grounds upon which his attention is solicited to them are private and personal.

I feel assured that every one possessed of fraternal feelings will enter into and justify those which prompt me to step forward under the following peculiar circumstances. Reasons for this biographical notice

While the great utility of my brother's inventions have on the one hand led to an unavoidable publicity, his retired habits and state of health, have, on the other, caused him to neglect seeking that position before the public to which his pursuits and character have assuredly entitled him, and which would have guarded them from erroneous and invidious remarks.

Even within the last and present year, an individual occupying the respectable position of a lecturer on Chemistry, having become popularly associated with a question of sanitary interest, has taken various occasions in connexion with the subject of Respiration, to publish statements respecting my brother, which had they any real foundation whatever, would compromise not merely his scientific but his moral reputation also.

It is not from any weight attaching to this person that I should have thought such statements demanded notice, but because, while he is by no means the first, he is the most forward assailant of one who need desire nothing more than that his pursuits through life should be thoroughly known. Not satisfied with having obtained for some of his statements the universal publicity of "The Times" newspaper, he has availed himself of the opportunity, in giving a lecture at the Royal Institution, to promulgate them from its theatre as *ex-cathedra*, and to advertise

the lecture afterwards before the public, who are not at all aware that the Council of the Institution repudiate all responsibility as to the correctness, or otherwise, of the statements of the Friday Evening Lecturers.

A bare statement of unanswerable facts would show this lecturer to have placed himself between the horns of a very unenviable dilemma, which I refrain from specifying, on points both moral and scientific; but I think more than this is desirable to put my brother in a right position with the public, before whom he has been so unwarrantably arraigned. Possessing such ample materials as those condensed into the following pages, I cannot but feel myself challenged to put them forth in the form of a biographical sketch, which cannot fail to prove abundantly confutative of invidious remarks, from whatsoever quarter they may proceed.

Mr. Jeffreys family and professional pursuits.

Mr. Julius Jeffreys, born at Hall Place in Kent, is the fourth* son of the late Rev. Richard Jeffreys, who succeeded his father, as Rector of Throcking, in Hertfordshire, and was also for some years a Chaplain on the East India Company's Bengal Establishment. In a private circle, to whom his retired habits confined him, he was well known as a profound mathematician and classic. Most of his sons were educated by him.

My brother studied medicine in Edinburgh and London, and prompted by recollections of India from childhood, looked to it as a field offering inviting opportunities for the cultivation of physical and experimental science, to which he was ardently attached; at the age of twenty-one he obtained from a friend in the India Direction an appointment in 1822 on the Medical Establishment of Bengal.

Essay on the Mechanism of the Joints and Muscles.

Prior to his leaving England he published, an essay connected with a complex subject—The mechanism of the chief joints and muscles of the human body. Amongst several favourable notices of it were the following from of the three most eminent surgeons of the day—Mr. Travers, Sir Astley Cooper, and Mr. Abernethy; with the two former of whom he was wholly unacquainted, and but slightly with the latter. In writing therefore in the following kind and flattering terms they could have been influenced only by the merits of the work.

* The family was numerous, fourteen having grown up, six sons, and eight daughters. Of the sons, three entered the Church, the eldest having been Archdeacon of Bombay, two having held fellowships at Cambridge, and one having been especially distinguished as a mathematician. Two entered the Indian Army, and one, the subject of this notice, the medical profession. Of the daughters, two married clergymen; two, members of the Indian Civil Service; and two, Military officers.

From BENJAMIN TRAVERS, Esq., F.R.S.

"New Broad Street,
"April 24th, 1822.

"My dear Sir.—I have perused this little volume with much instruction and "pleasure. I have no hesitation in saying that the author demonstrates his "statements very satisfactorily; and I can only express my regret at his "leaving Europe, both on professional and personal considerations. We have "very few young men equally competent to inform us.

"Yours, always sincerely,
(Signed,) "B. TRAVERS."

"Wm. Smith, Esq., M.P."

From SIR ASTLEY COOPER., Bart.

"May 18th, 1822.

"My dear Sir,—Pray make my best compliments and thanks to Mr. Jeffreys, "and congratulate him upon the golden promises of his son. The work "evinces a great deal of thought and talent.

"Believe me, yours truly,
(Signed,) "ASTLEY COOPER."

"J. Dobson, Esq."

From JOHN ABERNETHY, ESQ.

"Bedford Row,
"16th May, 1822.

"Dear Sir,—I think that Mr. Julius Jeffreys's book will do him credit with "the profession, for it shows a considerable extent of anatomical knowledge, "and also, that he is a thinking and reasoning character. Moreover, I believe "that his readers will all acknowledge the truth of his facts and arguments.

"I should have written to him to thank him for his book, but that I knew "not his address. I request then, that you may express my thanks, accompanied "with my good wishes.

"I remain, Dear Sir,
"Respectfully and sincerely yours,
(Signed,) "JOHN ABERNETHY."

"— Lloyd, Esq."

Essay on Attraction and Repulsion.

Having been dissatisfied, from his first attendance on chemical lectures in the University, with the popular account given in them, and in treatises on Chemistry of the statical condition of the molecules of matter in its three *states*—solid, liquid, and gaseous—that in the first the force of attraction is much superior to that of repulsion; in the second, that they are nearly balanced; and in the third, that the repulsion is much the greater force; as being not only insufficient, as any attempt in the existing state of knowledge must be, but unphilosophical as proposing an impossible condition in the two first states of matter, he made this branch of natural philosophy a subject of much study and thought, and collected his inquiries into an essay in 1821-2, the object of which was to clear the ground of imperfect arguments, and to offer a hypothesis which appeared reasonable to explain the case. Though the attempt might be considered presumptuous in one so young, and though he has had to correct some of the minor arguments, the main arguments were viewed very favorably by more that one

able mathematician, and it was proposed that the paper should be offered to the Royal Society.* But my brother left for India at this time, and his attention became directed to the following subjects.

Landing in India:—treatment of Cholera.

On landing in Calcutta, he was as is usual attached to the general Hospital. Cholera and fever were raging amongst the European troops. Of H. M. ill fated 44th† regiment, one half were in hospital. For some time more than a hundred sick fell to his charge, besides cholera cases of an acquaintance in charge of an adjoining ward, who became panic struck with the appalling severity and rapidity of the disease. An experience was thus rapidly acquired, which suggested certain views as to a peculiar state of the cutaneous capillaries being concerned in causing the specific symptoms of this disease, and guided his treatment of it throughout his residence in the country.

Tour in the Himalaya: Sanitary Stations.

After a year's residence in India, he obtained leave to make a tour in the North-West Hill Provinces, and conducting meteorological observations in valleys and on heights in the Himalaya range up to nearly 17,000 feet, he became satisfied that the prejudice‡ existing at the time against the climate was unsound, and that its peculiar element—a greatly diminished barometric pressure, as also its unparalleled equability—would prove therapeutic agents of much efficacy in the restoration of tropical invalids. At SIMLA, where only one house then existed, he collected his observations into a small work, recommending the formation of sanitary stations there and elsewhere. This work received very favorable attention from different functionaries, with an assurance that the attention of the government would be early directed to the subject. Accordingly a commission was appointed. SIMLA, with the other localities, were selected for sanitary stations, and it soon became a place of much resort. Many an invalid has found in the restoration of his health the anticipated action of the climate to be fully realized.

Surgical Operations.

In the hills, having by him only the ordinary pocket instruments of a surgeon, he removed from a native a stone which had passed out of the bladder and was lodged in the passage, where it had grown to a considerable size, and made for itself a sack. The rapid recovery of the sufferer, who was in a very critical state, produced so wide an impression on the people, that at each stage of my brother's journey, natives came with large wens, and other external diseases, seeking relief which could not be afforded them.

* This paper was published afterwards in the Journal of the Asiatic Society of Bengal. September, 1833.

† Destroyed afterwards in the Koord Cabul pass.

‡ Officers, and even the medical officers, stationed on the lowest range, expressed themselves strongly against a residence on the higher range of 7,000 or 8,000 feet, for any continuance.

Shortly after his return from the hills, he performed at Agra, on a native soldier, with an early cure, amputation at the shoulder joint; both these are serious operations.

Within two years after his arrival in India, the governor general was pleased to nominate him to the staff-surgeoncy of Cawnpore, the head quarters of the field army; a post so much above his standing in the service as to have led to a remonstrance on the part of members of the senior branch of the profession. The government, however, retained him at his post, assigning very flattering reasons for doing so.

Appointed Staff Surgeon of Cawnpore.

There he invented the "Refrigerator," a large blowing and evaporating machine, with a valvular pendulum piston oscillating in a quadrantal chamber free from friction, for cooling dwellings and barracks. Of the principle of this machine, as producing the utmost result from the power employed, the late Col. Forbes of the Bengal Engineers, an officer of the highest repute, used to speak most favorably. The large bulk necessary, as the oscillation of the pendulum occupied two seconds, rendered it less generally convenient than the centrifugal blowing machine of Deseguilliers, introduced into India by Doctor Rankin, with ingenious adaptations, and named by him the "Thermantidote."

Invention of the Refrigerator.

But before the lapse of two years his health compelled him to exchange to a less arduous post. Commanding more leisure, he renewed his favourite pursuits; and in endeavouring to apply the science of Europe to improve some of the primary arts of India, his efforts were thoroughly successful, and left nothing wanting but capital and enterprize on the part of the people to ensure a great advancement.

Between the years 1826 and 1830, he introduced the following arts, in a manner suited to the exigencies of the country, and of the climate: 1st.—Sulphuric acid works built underground to ensure a low and equable temperature, with an oxydating apparatus of a particular construction; in these works the sulphur yielded, a maximun product. 2nd.—Vitreous and other stone pottery for various chemical uses. 3rd.—Fire bricks, not only equal to, but surpassing those of Stourbridge, in refractoriness and durability. Possessing these he constructed furnaces in great variety, vertical kilns of large dimensions, boiler furnaces, and reverberatory furnaces, for the manufacture of soda from the sulpho-sesquicarbonate, a valuable but nearly neglected mineral, and for other purposes, one very large one of a particular construction for the refinement of saltpetre; in these different works which contained a variety of machines, all made on the spot, and in which from 500 to 1000 native workmen were trained and employed for several years, my brother had no aid from without, but had to devise or teach himself everything; for he had seen none of the manufacturing

Introduction of useful arts into India.

operations in such arts before leaving Europe: while the natives were themselves in abject want of such information. They had no fire-bricks, and therefore no proper furnaces, no stone pottery, and nothing but the commonest ware of a red and porous body, burnt at a low red heat only. They could not melt cast iron, nor even weld it on any but a small scale, in a feeble forge; some of these operations were performed in the government works with means from England, but where unknown to the natives generally. The difficulties attendant on the establishment of such works, especially those of perfect viterous ware and fire-bricks, were such as perhaps no one would imagine. Minerals were sought from all accessible strata, within an area of many hundred square miles; hundreds of specimens were analyzed, and many hundred compositions made, and subjected to experiments; occupying many a night as well as days, through a long period of time.

Papers on Schools of useful art.

He subsequently embodied, in different papers, a variety of arguments to induce the government, as an act of duty to the people, to establish schools of useful art in India.

Inquiries on Canal and Well irrigation.

His attention was also directed to the arts of agriculture there, and more especially to irrigation. To the subject of canal irrigation his attention was first drawn in 1824, when stationed at KURNAL, where the canal of the Emperor FEROZESHAH had been recently re-opened, and was manifestly a source of malaria and sickness amongst the troops quartered there, especially amongst the European artillery, of whom my brother then had charge. On examining the course of the canal, he became of opinion that the constantly varying level of the water was the chief cause of the evil: by alternately soaking and exposing slimy banks to the air and sun. It was plainly a mere act of carelessness to allow the irrigators of lands to disturb materially the level of the water; as in the long run more cannot be drawn out and evaporate from a canal than flows into it from its source of supply, he became convinced, from observation, that a tropical canal ought at all times to be kept full, as it would then be much less injurious as a source of malaria, and as it would thus be also available for navigation, which would render it an additional blessing to the people, and source of revenue to the government constructing it, while the requirements of navigation would ensure the water being kept at a proper and equal level.*

Invention of Hydraulic Apparatus, and Wind-mill.

And with respect to wells—the source from which half the Bengal territories are irrigated—having proved by a series of careful experiments the native method of raising water from them, to be very wasteful of labour, he invented more than one kind of

* At the same time it would be prudent not to carry the course of canals within two miles of European stations.

hydraulic apparatus and windmill, of the originality and action of which, mechanicians of the first ability have spoken highly.

The reader, whose attention has been directed to the important question of Indian improvement and to the recent discussions on canals, irrigation, and railways, for India, will not think a brief notice of my brother's views uninteresting.

Papers on Indian industry, roads &c.

By persevering investigations, and at no small expense in experiments, he arrived at information of a curious and important character on the state of the arts of India severally, on the productiveness and waste of labour, on the application of science to the arts and industry of the country, and the philosophical and economical results deducible therefrom. In papers, in public journals, and in letters to the government, part of this was set forth. From Lord William Bentinck, then Governor-General, he received a very polite and friendly attention, although he had reason to know that his lordship had previously been in some degree dissatisfied at his having stated somewhat too plainly his chief reason for declining a flattering nomination to the government's chief opium-works at Patna.

Lord William Bentinck, who favoured my brother with frequent interviews, was kind enough to express more than once a wish that he would remain in India, and to hold out every encouragement to him; but his health had suffered too much by over-exertion and exposure to the climate. The following extracts from his lordship's letters and from one of Lord Metcalfe and Mr. Mangles, will suffice to show the estimation in which his character was held by men of the first note; and to these might be added letters from other Indian statesmen:—

From LORD WILLIAM BENTINCK.

"May 20, 1834.

Letters from Ld. William Bentinck.

"Dear Sir,—I read your first letter signed 'Aristobulus,' and I immediately "pronounced it to be yours. It is gratifying to me to find so great a concur-"rence between us upon the subject of the wants of India. I remember "reading, at the time it appeared, your letter on roads for India. I have also "read with pleasure and interest your letter of the 29th of April. I suppose it "may take a century to raise India to the English standard. But it is only by "the contributions of those who have the good of mankind for their object, and "care not for disappointments, that any advance can be made upon the "universal ignorance and poverty. I trust you will not be discouraged, &c.

"I remain, dear Sir, your faithful servant,

(Signed) "W. BENTINCK."

"Julius Jeffreys, Esq. May 29, 1834."

"The papers you have at different times addressed to me, together with the "letters now under publication, signed 'Aristobulus,' bear ample testimony of "the just views you take," &c. &c.

"The scientific improvements that you have actually brought into successful

"practice, and the experiments you are now engaged in, are also the best proofs "of your mechanical and inventive powers. I have no doubt either, that your "exertions are influenced by a sincere desire to promote the welfare of your "fellow-creatures.

"I remain, dear Sir,
"Your faithful servant,
"Julius Jeffreys, Esq." (Signed) "W. BENTINCK."

From LORD METCALFE (Then Sir C. Metcalfe).

"23rd September, 1834.

Letter from Ld. Metcalfe

"I sincerely lament the necessity which compels you to seek "health in a more genial climate. I take the greatest interest in your im- "portant experiment. If you facilitate irrigation, you will render the greatest "possible benefit to India, and especially to Upper India. Many thanks for "your specimens of stone ware;* they are admirable.

"I remain, my dear Sir, yours very truly,
(Signed) "C. T. METCALFE."
"Julius Jeffreys, Esq."

* A manufacture successfully introduced into India by Mr. Jeffreys as the basis of the chemical arts.

From ROSS D. MANGLES, ESQ., M.P., Late Secretary to the Government in India.

"10th April, 1834.

Letter from R. D. Mangles, Esq.

"My dear Sir,—Many thanks for the copy of your letter to the *Courier*, "which I estimate very highly as a publication of political and philosophical "truth, and will preserve with proportionate care. For the sake alike of the "government and the people, I am truly sorry to hear that you are about to "leave the country. I am equally sensible of your public worth, and the value "that ought to be set upon your talents for rendering good service to the state. "Your views, I am convinced, contain the germ of almost incalculable im- "provement.

"Yours very truly,
"Julius Jeffreys, Esq." (Signed) "ROSS D. MANGLES."

Pitching motion of Ships

On his way from India my brother invented a method of converting the rolling and pitching motion of ships becalmed at sea, or opposed by a head wind (useless and damaging to the vessel,) into a useful and progressive motion.

A distinguished mathematician made this plan the subject of an able investigation, proving it to be *theoretically* sound; but it has not yet been subjected to trial.

Proposal of lectureship.

On his return to England in 1835, through the introductions of these noblemen and other friends, he formed the acquaintance of most of the East India Directors, and put before the chairman the proposal of a lectureship on the application of science to the arts of Asia, with the view of offering to young men, proceeding to India in the different branches of the service, information which they might afterwards, as opportunities were offered them, diffuse amongst the natives throughout the country. The then chairman, Sir James Carnac, expressed a very favourable opinion of the proposal, and wished it should be prosecuted

further; but my brother, while he entertained the highest respect for his friends in the Direction, felt that his own views as to the rights of India did not sufficiently correspond with those of the Court generally, and he refrained from troubling them further with his plans.

Some of the objects of that proposal were obtained by the subsequent employment, in a somewhat congenial capacity, of another medical officer from India, Doctor Royle, whose great ability as a botanist especially qualified him for examining and reporting upon the produce of India and its improvement.

He now felt that he had neither strength nor time to spare any longer from other duties in the vain efforts to promote Indian improvement. Compelled with much regret to withdraw from the subject, he closed his labours by writing three papers in the autumn of 1835 on the resources of India and the duty of England in the "London Asiatic Journal." After a philosophical inquiry into the distribution of the population, the products of their industry, and the produce or rent available as revenue, and into the wants and claims of India and the duty and policy of England, he gave an outline of the results of his own inquiries and of some of his practical efforts. Amongst other points he urged the importance of canals jointly for irrigation and navigation, and dwelt particularly on the importance of a canal to run throughout the Dooab (now the great Ganges canal), for irrigating the central tracts of that province* and for relieving the rivers of their tardy, difficult, and dangerous navigation. The character of all those rivers of India with which he was acquainted (having traversed two of the chief, throughout the whole of their course, from the rise of some of their tributaries in the hills, and having in tedious journeys up and down them, paid a close attention to such river navigation) established in his mind the conviction that inland navigation in India ought, as far as possible, to be transferred to canals fed by the rivers, which canals ought to be the sources of irrigation for all lands near their course †

Papers on the resources of India, canal irrigation, &c.

* This great work, the merit of projecting which for irrigation appears due to a very able officer, Sir Proby Cautley, is, I believe, still confined to that object chiefly.

† Compelled so long to withdraw from the field himself, it has been a source of great satisfaction to him to note Colonel Cotton's extensive and successful efforts in it, in another Presidency—Madras, and his undaunted perseverance in urging the duty of Indian improvement upon the people of England. Although it is probable Colonel Cotton has never seen my brother's writings, published long ago, the views set forth in his lectures upon the distribution of the population, their wants, and upon irrigation and inland navigation and transit, bear a remarkable and confirmatory similarity to many of my brother's. It is with regret that he is compelled to differ from Colonel Cotton upon one point—the expenditure of efforts upon the improvement of river navigation. For reasons too numerous to be recounted in this abstract,

At the same time the importance of improving irrigation from other sources, and especially that from wells, was strongly urged, whether the simple hydraulic machines, proposed by himself, were adopted or not.

Invention of the Respirator.

At this period, in the autumn of 1835, my brother was led, through the wants of a sister, to invent an instrument—the RESPIRATOR, by which his name has been chiefly known to the public in England. The peculiarity and importance of its objects, and his having been under the necessity of taking out a patent for it, prompted immediately upon its introduction remarks in one or two quarters of no very generous kind, which have from time to time been repeated, until a lecturer, who had recently made himself known in connection with a popular object; and who was evidently unacquainted with my brother's circumstances, has allowed himself to indulge in various statements on points, moral as well as scientific, which to say the least of them, are as ungenerous as they are utterly opposed to truth; while they are accompanied by a patronising air, which is somewhat amusing.

Refutation of attempts to disprove the originality of the Invention.

It is the universal publicity of *The Times*, which has been obtained for some of these statements, and the apparent authority of the Royal Institution for others, which compel me to request the reader's attention to a total refutation of them, which I will endeavour to render as brief as possible.

My brother, it is well-known, introduced the instrument, to which he gave the name Respirator, as an original invention, and has always received credit for it as such, and for the justice done to its principles; whereas he is charged with patenting an invention already existing, and recently lectured upon by another, and carrying it out in a sordid and defective manner!

These charges are commenced with the assertion that "Respirators are an older invention than is commonly supposed." To prove this, a passage is first quoted from Doctor Beddoes, who wrote in 1802, and it is then added, "it is evident from these extracts, that Dr. Beddoes, so early as 1802, was perfectly aware of the mode of construction and operation of Respirators." It ought to have been said, "It is evident from these extracts, that Dr. Beddoes was not at all aware, either of the construction or the operation of Respirators;" as that truly able and honourable man, were he alive, would himself affirm; while he would by no means thank the lecturer for bringing forward one of the few passages in his valuable writings in which he was in error. Having heard that folds of crape guarded the faces, and to some extent the lungs, of Alpine travellers, from the cold dry air of those

of his observations, reasons in which, as an old Indian myself, I fully concur, funds devoted to canal navigation in India, promise to be tenfold more advantageously and successfully laid out than in general upon the rivers of the country.

regions, he committed the oversight of recommending such "muzzles," *of crape,* for pulmonary sufferers. He thus fell into the common mistake of supposing *non-conducting* matters, such as wool, &c., to be proper agents for protecting the lungs, because they are the most suitable as clothing for preserving the warmth of the skin. The crape muzzle was but a feeble form of the coachman's woollen "comforter." The action of wool, either in the form of a "comforter," or of a "crape muzzle," is simply and only this :—It detains mechanically in its folds, some of each outgoing stale breath, which, mixing and returning with each entering fresh breath, imparts to it a proportional amount of warmth and moisture. For the coachman who requires but a slight warming of his fresh breath, and can bear for this end a little return of each impure breath, the woollen "comforter" or "muzzle," may answer, but the delicate and suffering, on the one hand need much warmth and moisture to be given to a cold atmosphere, and on the other, are oppressed by a very little return of their impure carbonic acid. Directly Dr. Beddoes put the idea in practice, he must have found how totally it would fail of its object, for persons delicate in the lungs. A wrapper of non-conducting matter, to have any adequate warming effect for them, must be so bulky as to detain an amount of each stale breath, quite suffocative. Hence, though he subsequently wrote at great length on influenza, then prevailing, and on consumption, and was anxious to devise all methods of relief, proposing spacious buildings, of tempered atmospheres for patients to take exercise in, he never again names the crude suggestion. So far was he from having invented the Respirator, that he had unfortunately been drawn into a wrong path, with his back to the right principles, by the false analogy of warm coverings for the skin. It is well for invalids that my brother never saw the passages in question, nor indeed Dr. Beddoes' work containing them, until they were thus exhumed, for their tendency would plainly be to misdirect the judgment and stand in the way of the independence and originality of thought, necessary for inventing the proper instrument, composed solely of highly conducting matter.

Have the invalid public or not, a valid ground of complaint that in this quotation, and in subsequent remarks, in a lecture *delivered at the Royal Institution,* the fact of so much importance to them should be ignored, that the *principle of conduction,* and the *use of metal,* constitute the very essence of a proper Respirator, and must form the substance and burden of any right description of it, just as much as latent heat, expansion, condensation and metal, must enter into any proper description of a steam engine?

To say that Dr. Beddoes was the inventor of Respirators, merely because he saw warmth and moisture to be desirable for his

patients lungs, although he proposed means not only totally inadequate, but acting upon principles the very opposite to the proper ones, is not a whit more reasonable or just, than to affirm that the man who first proposed relays of horses for carrying news, was the original inventor of the electric telegraph, because he had in view the same object as this invention, viz. :—the utmost possible dispatch in communications between distant places.

Refutation of a libelous charge of piracy.

If the reader will not be struck with either the candour or the generosity of this endeavour to bring discredit upon the originality of my brother's invention, what will he think of the following assertion, directly charging him with a piracy of the grossest and most sordid kind? Were there any truth whatever in the statement, my brother's loss of reputation as a man of science, would be the smallest part of the charge. His moral reputation would be justly and irretrievably damaged. The lecturer says:—"Dr. Arnott informs me, that about seventeen or eighteen years ago, the principle and mode of constructing Respirators were fully described by him, in a lecture delivered in this very room; and a short time afterwards, a patent was taken out by Mr. Jeffreys for the manufacture of Respirators." Here is a statement of facts which have not the shadow of a foundation. That Dr. Arnott could not possibly have made such a mis-statement the following facts will show.

My brother, on his returning from India, as already stated, early in 1835, found his sister, Mrs. Nicol, widow of the late Adjutant-General of Bengal, in a state of advanced pulmonary disease. It was while concentrating his thoughts upon her case, with the desire of mitigating her sufferings, that he traced much of them to the effect of each inhaled breath upon the lungs, robbing them of more *warmth* and *moisture* than in their delicate state they were fitted to supply. To transfer these elements to each incoming breath, without detaining the stale outgoing breath, he next discerned to be the desideratum, and to effect this by conduction, and therefore by metallic agency, were the consecutive steps in the inductive train of thought, into which, for her sake and others, he was fortunately led. He constructed such an instrument for her. Though rudely made, the relief it afforded her at once prompted the trial of several on other persons, with like effects. To extend the benefits to the invalid public was plainly the next duty. It is well that all the moral difficulties did not then present themselves. He saw difficulties enough, however, to render the protection of a patent *absolutely necessary;* and on seeking in December, 1835, the judicious opinion of Messrs. Poole and Carpmael of the government patent office, as to the possibility of inducing the public to afford due attention to such an instrument, he was recommended by them to

obtain the opinion of Dr. Arnott. The latter, whom he saw in that month for the first time, manifested no previous thought of, or acquaintance with, the principles of the instrument whatsoever, and did not indeed, appear quite to assent to its action until he made trial of it by respiring through the one Mr. Jeffreys showed him. The name "Respirator," which Mr. Jeffreys had given it, was of course equally new to him, and commented on by him as such.

The patent was taken out in *January* 1836, and on the 11th *of March following*, Dr. Arnott, while lecturing at the Royal Institution on the subject of warming and ventilation, introduced the subject of the Respirator, *the name and nature of which he had recently learnt from Mr. Jeffreys.*

In publishing widely so offensive and emphatically pronounced a libel against a gentleman who had never wilfully done him, or any other of his fellow-men an injury, it would be a poor excuse to say that some conversation with Dr Arnott had been mistaken.* To strive to deprive a neighbour of the credit of an invention, which has acquired a world-wide reputation, is not a small offence, but it is as nothing when compared with the charge of pirating it from others for the sake of gain—with having held, therefore, an illegal patent, and a falsely assumed credit and reputation.

I will not intrude upon the reader, who, I hope, has no personal interest in the virtues of Respirators, a lengthened examination of the tissue of errors indulged in by one who, in the anxiety to strain an instrument of his own composed of non-conducting matter far beyond its legitimate purpose, ignores the facts, that any respirator, properly so called, should contain *nothing but the best conducting matter*, and that a copious condensation of moisture is not only an essential virtue in its action, but the very measure of its warming power; so that in proportion as it condenses little, it must be a feeble warmer of the inhaled air. I will not occupy space by showing that my brother's instrument is actually confounded by him with an imitation, faulty in construction and action, brought forward by a friend of the lecturer's; and that statements are made altogether opposed to science and fact, while impossible effects are promised from the instrument introduced by the lecturer. An *attentive* perusal of that published lecture will fully confirm all this, but I must introduce one instance. While it is stated, that my brother's purely metallic instrument is obstructive to the breath, (although, of course, no more metal work is introduced than is necessary for the effects, and that of the least obstructive nature,) the pulmonary sufferer is recommended to burden himself with a wall of *non-conducting* charcoal in lieu of most of the metal, on the ground of the assumed importance to him, that

* A reference to the records of the Patent Office and of the Royal Institution ought at least to have been made previously.

the impurities of his own breath should be corrected by breathing through charcoal! Now such impurities are of course lodged in the outgoing breath, the purification of which is not only useless to him, but involves, in its very process, a detention and accumulation of the main impurity, Carbonic Acid, in the charcoal; this substance having the peculiar property of condensing into its pores thirty or forty times its volume of this gas, and when saturated with it, as when expired through it must in a few minutes become, of also, as is well known, giving some of this gas out again to a current of fresh air conveyed through it. So that if the charcoal has any action at all, * its tendency is to contaminate the fresh breath with the undecomposable impurities of the stale. Now a proportion of this gas, so small as to be imperceptible in breathing, and, barely perceptible by analysis, suffices to render many atmospheres very unwholesome.

Invention of Machines & processes for making the Respirator.

My brother feels that he has already so fully acquitted himself of the duty of explaining clearly to the invalid public the proper principles and construction of Respirators, that if any persons allow themselves to be misled by specious statements, and any apparently reliable authority, the fault will be their own. At the same time, few persons are aware how much inventive thought was devoted to the object of realizing in the best manner the principle of the Respirator. To give a vertical structure to the wirework for carrying down superfluous moisture, and to keep the several layers distinct from each other, for commanding the gradative conduction of heat, on which much depends, my brother determined to fix the wires down upon lattices of metal, and invented a machine for punching these lattices, which, in the difficult process of fine longitudinal punching, is perhaps unequalled in the art. The ablest machinist in the art, who introduced the fine card and metal perforating, supplied the first lattices for the Respirator, but they did not come near to my brother's requirements. On seeing the first lattices pierced by the above machine, the finer bars of which were one-sixtieth of an inch thick only, though half an inch long, his surprise was great; and he added that a machine so delicate could last but one day. It has been in use for eighteen years, and has pierced more than a

* The truth is, if charcoal is respired through, it soon becomes humid, which, fortunately, so far impairs its catalytic power, as to render it perhaps comparatively inert and harmless, excepting as a mass of non-conducting matter, presenting obstruction, without conducing in any degree to the proper effects of a *Respirator*. But if used as an *Inspirator* only, (a caution indeed given by this lecturer himself elsewhere,) the charcoal instrument may be of much value to protect a person who has to expose himself to an infected atmosphere; and it would be well for his own credit, and for those whom he may influence, if the lecturer had confined it to this, its legitimate purpose. And with respect to an invalid's breath: in a case where it is so very impure as to infect his apartment, is it not plain that the only safe and proper way to employ charcoal to correct *that*, would be to suspend an abundance of the powder in trays about the room, and not to propose to him to breath *both ways* through a saturated wall of it before the mouth.

million lattices. The machine for laying the wires down parallel, and the peculiar processes for soldering them, by which, without a blot or failure, 40,000 or 50,000 minute points of soldering are effected in each respirator, are also quite original. Judges of the first ability have examined the operations, and have invariably expressed much admiration of them. In evidence of this, one communication will suffice, conveying, as it does, the opinion of the first mechanician of the day.

Letter from C. Babbage, Esq.

From C. BABBAGE, ESQ., F.R.S.

"Dear Sir,—On my return to town, I found a parcel containing the specimens "of various processes in your beautiful manufacture, which I had examined "with so much pleasure and admiration. I also found a complete example of "the finished result, accompanied by your obliging note. I shall preserve it "as a memorial of a manufacture which is equally beautiful in the perfection "of its detail and the philosophy of its contrivance.

"I am, my dear Sir,
"Very faithfully yours,
"C. BABBAGE."

J. Jeffreys, Esq.

To the pains, ingenuity and science exercised in giving effect to the invention, no less than in the conception itself, are due the beneficial results which have given so wide and high a reputation to the name "Respirator," that the assumption of the name for all manner of absurd and defective imitations secures for each, as it appears, the confidence of the ill-judging amongst the public. Some of these are merely multiplied folds of common non-conducting fabrics, others merely shells of pierced metal, which would have no effect if the current of the breath were not obstructed in passing through them by the aid of cloth.

Since the reader is probably aware that many thousand persons are every winter deriving relief from my brother's invention, I need scarcely have brought evidence to establish my point that in all that relates to its philosophy and construction it does not do discredit to his antecedents. And it is quite unnecessary that I should trouble my readers with any of the multitude of letters, from all quarters, abounding with expressions of gratitude for benefit imparted by his invention. Not a few are from members of the medical and other professions, who state that it has enabled them to remain in England, and in active practice, and thus to provide for their families.

Refutation of other groundless charges.

But there are other moral points also, upon which the lecturer and correspondent of newspapers has taken every opportunity to give circulation to statements which have caused my brother far more *personal* concern than any sophistical criticisms on the Respirator.

There can be no question that any man of science, who shall look to his own convenience and advantage only, will do wisely not to take out a patent for an invention having a remedial object. Though, unlike drugs, it shall involve a mechanism requiring the

exercise of no skill in its employment, it is liable to be ranked in the category of "medicines" over which, as the legitimate tools of the physician's skill, any kind of exclusive right is discountenanced. Whatever be the nature of the inventor's professional avocations, he will generally gain more reputation from an invention, the merits of which he is free to proclaim as having retained no property in it, than by incurring the risk, the annoyances, and the responsibility of carrying it into effect himself. At the same time there will naturally be established in his own, and others minds, a conviction of the entire disinterestedness and benevolence of such a course.

Against any one's taking this course, though by no means the best for the public, I would not presume to say a word, but I have a valid ground of complaint that any person occupying a respectable position, should not only in the universal columns of the *Times*, but even in the Theatre of the Royal Institution, take the great and unbecoming liberty of dragging from retirement my brother and his procedure as a background for his own picture—a foil to set it off; that after telling his audience that in justice to himself he thinks it right to state that he has not made a property of his invention on the principle that means for the prevention of disease and death, in order that they may bear the lowest possible price, ought not to be made the subjects of patents, he should contrast with this my brother's course; instancing the Respirator and stating that a price five times as high was charged for it as that borne by the instrument introduced by himself; speaking also from no authority, of the great source of emolument the Respirator had been to my brother.

Were the facts of the case, as he states them, this would be no modest or generous course towards a fellow-labourer in the paths of science; but they are the very reverse. The article for which the name *respirator* is borrowed (but, which ought to be named, and used only as an *inspirator*), consists of two layers only of the commonest wire gauze, washed with silver, worth a few pence, containing between them a wall of ground charcoal, which cannot cost a farthing. The price of this unpatented article is six shillings. I beg the reader will compare with this the character of the Respirator for many years provided for the working classes, priced at five shillings. This instrument has always contained not two, like the other, but eighteen layers, on nine frames, and not of common gauze, but of a manufacture perhaps the most delicate and unique in the fine arts in metal. It is not only lower priced absolutely, but compared with the quantity of workmanship in it, instead of being five times as dear, it is not one-fifth the price of the other.

As to the large emolument my brother is assumed to have made, the statement is altogether incorrect. The patent itself, as such, has yielded absolutely nothing. While my brother has felt it a duty to contrive and control the manufacture, he has left the vending to others. So heavy have been the expenses unavoidably attendant on giving publicity to, and removing prejudices from, a novel and peculiar remedy, that they have absorbed more than any royalty obtainable from the patent, and have caused the returns on the manufacture merely as a wholesale business, to be less than those of any manufacture of like fineness unprotected by patent. They have, in short, gone to make its benefits known to myriads who would not otherwise have heard of them, and thus to establish a well-founded reputation for the name Respirator, for the charcoal and other articles to borrow. "Sic vos non vobis mellificatis apes."

Refutation of mistaken reports as to the lucrative character of the invention.

With respect to the general proposition—that means for the prevention of disease and death ought not to be the subjects of patents, it is unsound in principle, and unsupported by custom. It is not acted upon even in that circle in the medical profession in which it has been somewhat arbitrarily propounded. On that principle, assuredly the copyright, which is the most exclusive form of patent, ought not to be retained for a medical work full of information "for the prevention of death and disease." Such works, instead of bearing as they commonly do high prices, ought to be thrown open for publication at the "lowest possible price," that the most needy practitioner might be invited to study them for the good of humanity. Indeed, as by the wider circulation of an able work more would often be gained in reputation than by the copyright, many an author would no doubt adopt that course, but for professional etiquette, which actually discountenances it; and perhaps rightly. But it is absurd in the same breath to discountenance patents for inventions having a remedial object, and to affect a disinterestedness which the great and the good do not pretend to. Noblemen of the first rank and worth have held patents for agricultural instruments, while it is notorious that agriculture is retarded by the unwillingness of farmers to pay the prices of new implements. Yet, if any thing ought to bear "the lowest possible price," it is "the poor man's staff of life." So much for actual practice in collateral cases, both in the profession and out of it.

Refutation of a false proposition respecting patents.

Again, when professional inventors are by their position and disposition rightly prompted to write and lecture their plans into use, a patent may not be necessary for the introduction of them; and such inventors will assuredly, in the present state of the profession, consult their own advantage in every way by avoiding any business concern in them; but in general, especially where an

invention is for an object altogether new, the expense, risk, time and trouble, required for establishing it, even with a patent, are so great, that no one in his senses would incur them without one. Henee the interests of the publie are seriously eompromised when the proteetion neeessary for eneouraging really novel inventions is deeried.

Trne principle guiding the tenure of patents for remedial instruments.

Furthermore, sinee it is indeed desirable that "inventions for the prevention of death and disease should be sold at the lowest possible price," that is, *for the poor*, and, so far as is eompatible with effieieney, the man of well-judging benevolenee will not negleet to ineur the risk and trouble of a patent, even though he may not be under private obligations rendering it a duty. By so doing he ean, while ensuring to the rieh the invention in its perfeetion, draw from them a fund (utterly trifling indeed compared with the value of the invention to them) eommanding whieh he may ensure the poor being literally supplied at "the lowest possible priee," namely, at the bare eost of produetion. And when he finds, as he will find, that by the time disease has urged them to seek aid from the invention, it has redueed many to sueh indigenee that it is as mueh out of their reaeh at "the lowest possible priee" as at the highest, he may have the satisfaetion of direeting, that in all sueh eases duly eertified, it shall be promptly and gratuitously supplied without limit, and without the ostentation of himself getting up a eharitable soeiety for the purpose, or the greater ostentation of everywhere proelaiming in lectures and newspapers his meritorious self-denial in avoiding the risk, the annoyances, and the duties of a patent.

Again, if an inventor is not independent of private obligations and ties, let him bear in mind where the first duties of life eommence, and let him beware lest that great snare, the fear of man, or that greater, a love of applause, shall entrap him into neglecting them, and into ineurring thereby the seriptural denuneiation of being "worse than an infidel."

These are, beyond a question, the moral grounds, publie and private, whieh render it not allowable only, but in general the duty of an inventor of an instrument for the prevention of death and disease, to establish his control over it by a patent.

As to the publie, if every eare has been taken to provide them with the invention in its most effeetive form, they have no business whatever with the question whether it is upon publie or private grounds that the patent has been held, or whether objects eonneeted with both have been felt to require it.

My brother has had no desire to trouble the publie with information in whieh of the three positions he has stood, but having had to refute the gross and unfounded imputation that he had pirated the invention in the first instance, and then taken a

covetous advantage of it, I feel bound to state that my brother has not only employed the control of the patent to ensure for the working classes the full benefits of the invention at the lowest price, but has from an early date authorized this valuable instrument being supplied gratuitously, without stint or limit, in every case of certified need of it and indigence. To the promptness with which this rule has for many years been carried into effect by the managers, medical men in all parts of the kingdom can bear witness.

It is doubtless believed by many that the Respirator has yielded a rich harvest to its inventor. In this they are not mistaken. But the harvest, as my brother has elsewhere remarked, is assuredly not one of opulence, which has been neither coveted nor acquired through it. It has been productive of so frequent a crop of invidious remarks, that had it not yielded another harvest still, it would have been to him more advantageous and satisfactory in every way to have consigned the invention to oblivion at its birth, and to have employed the time and capital devoted to it in another and a quieter channel. From all parts of the United Kingdom, from the continent of Europe and America, from the southern hemisphere, and even from the tropics have flowed in expressions of gratitude, for benefits often described of a character not to be estimated in money. These are its richest harvest.

I now gladly pass on from the vexed question of the Respirator.

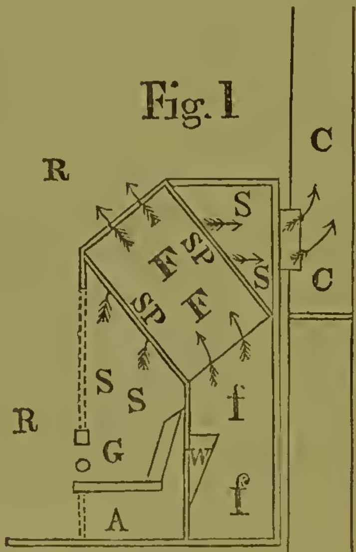
Invention of Pneumatic grate.

Immediately on his return to England, and prior indeed to inventing the Respirator, he was struck with the absence of all provision for ventilation in English houses, and was led to contrive a ventilating grate, which, while showing a bright fire, warms, by means of the waste heat, fresh air introduced copiously into rooms by the skirting board or otherwise; but not as in other attempts of the kind with open fires (in this and other countries) in which the air introduced is overheated. As the plan required much elaborate iron-work, rendering it expensive, he, two years afterwards, undertook to contrive a line of manufacture by which it was actually produced at one-fourth of the cost at which it could be made by hand. Nothing but the unaccustomed form, necessary for its proper effect, which was not inviting to the eye, prevented a more general use of it. It has warmed for many winters with perfect effect, and putting an end to cold draughts, rooms of large dimensions, and with numerous windows, which were far less comfortable with fires of two or three times the volume and consumption. Every judge of iron-work who has examined one of the grates so made has noticed the novelty of its style—applicable to other manufactures in iron—and its perfection and cheapness. But though he offered the factory

he built for the purpose at Birmingham, and the peculiar machines it contained at their bare cost, to any party whose business lay in that way; and, would have made over all claim to the invention on a promise that it should be introduced with spirit, it was for dwelling rooms judged not suitable in form to the public taste, while an endeavour to strain the principle to suit familiar forms had damaged the action and brought discredit upon it prior to my brother's taking in hand to contrive its manufacture. To continue it being out of the field of his pursuits and opportunities, the works were disposed of for other purposes.

Fig. I. represents a prependicular section from front to back of this stove as constructed by him; affording a side view of its interior. There was not a single rivet in it, nor any ordinary seam, every junction was effected by a peculiar and novel process of "quilling" with split tubes. Though only about the cube of two feet in bulk, it contained an open fuel grate G., ash-pit A., smoke space above *ss.*, smoke passasges between the tubes SP., and smoke chamber beyond them SS., fresh air chamber below *ff.*, eight or ten fresh air tubes FF., supplied with air from without

Fig. 1




and a hot-water vessel W., for tempering the dryness of the warm air. CC. the chimney. RR, the room warmed and ventilated. So mild was the warmth it yielded that the exterior of this stove was neatly japanned; while thus made, chimneys never smoked with it.

Invention of a smoke consuming furnace.

Based on a series of experiments, extending over some years, in the construction of furnaces and the use of fuel, conducted by him while introducing different arts into India, my brother many

years ago contrived a furnace for steam engine-boilers, which, from its nature, could not possibly yield smoke. Two or three well-known engineers, of much experience in steam engines, to whom the plan was exhibited, spoke of it at once as peculiarly original, promising, and deserving of trial; but the plan, not having been reduced to practice, has not been officially submitted to the Admiralty, which never takes cognisance of any but such.

Of this Boiler Furnace, an outline is given in Fig. I., as its peculiar character, and the importance of the smoke question may render some account of it interesting to the reader.

Fig 1

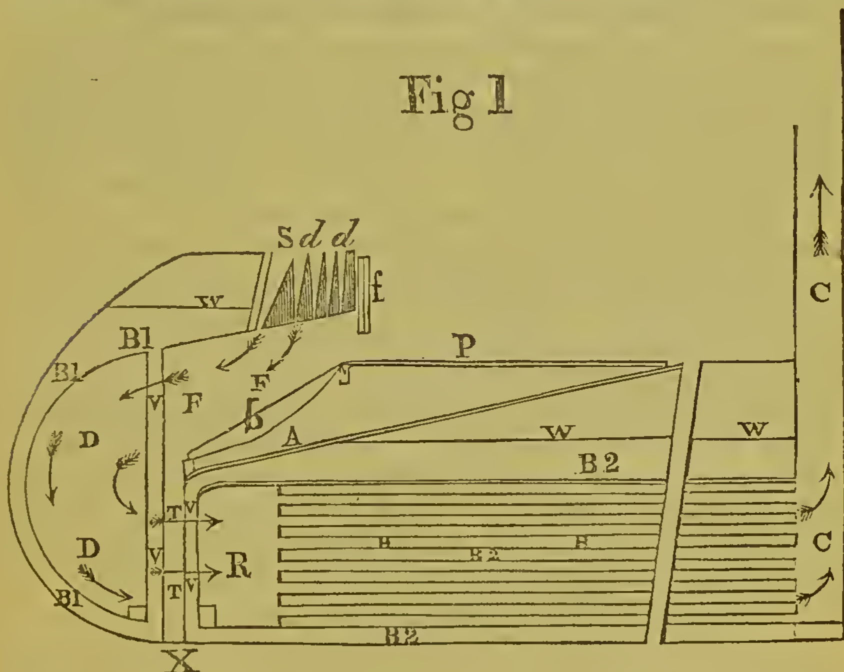



Fig. I.—Vertical longitudinal section of Vertical Boiler Furnace.

A.—Ash Pit.
BB.—Boiler Spaces.
b.—Fire Bars.
CC.—Chimney.
DD.—Deflecting Chamber.
dd., &c.—Draught Slits.
FF.—Front Furnace.
TT.—Trench Furnace.
f.—Furnace Door.
HH.—Horizontal Tubes.
P.—Platform.
R.—Flame Reception Chamber.
S.—Stoking Slit, Commanding the back of the fire.
VV,VV.—Vertical Trench furnace tubes.
WW.—Water Line.
X.—Slag Tray.

The original furnace on which this is based, was made as long ago as the year 1829, but it was for wood fuel. The current was carried horizontally through a vertical wall of fire, and then downwards, into the lower part of a furnace. This present plan, for coal, was invented fifteen years ago, with the whole fire vertical, and some years afterwards, my brother proposed to have the front part of the fire in an ordinary inclined furnace, FF., and for the

bright fuel only to lie in a vertical trench TT., beyond it. The smoky current from the fuel in F. passing between a long row of parallel tubes, VV., sweeps round the concave Deflecting Chamber DD. of the boiler Bl., and is ignited in re-entering and passing through the bright fuel in T., a trench formed by the two rows of vertical water tubes VV. The bright current collecting in the reception chamber, R., in the boiler B. 2, then traverses the numerous horizontal tubes, HH., of this boiler, to the chimney C. In the furnace originally made, the dust and clinkers all melted and ran down as slag to the bottom. At X., is seen the end of horizontal slag trays, to be drawn out occasionally. Into further details, I will not intrude on the reader's time by entering.

Treatise on the Statics of the human chest, &c.

But to practical science my brother's mind has by no means been confined, as, indeed, has been already shown. His inquiries in science have been various. In 1843 he published a work on certain abstruse and interesting branches of physiology, which was a collection of original observations made chiefly in India. Subsequently to the publication, he learned that in a few of those relating chiefly to the first of the three divisions of the work, he had been anticipated by Dr. C. Holland, a physician and physiologist of talent in Yorkshire, which may be received as a satisfactory confirmation of their truth. The bulk of the work, however, was quite original, not only as regards himself, which was the case with every part, but as to the publication also. The following letters, the two first being kind replies to myself, selected as those of physiologists of the first eminence, will show their individual opinions of this work. With Dr. Prout, my brother was acquainted only by name; they were not known to each other by sight.

From SIR BENJAMIN BRODIE, Bart., F.R.S.

" Broome, Betchworth, August 13th, 1855.

" My Dear Sir,—Your Brother was so good as to send me formerly his work " on the Statics of the Chest; and I remember to have read it with great " interest, and to have found that it contained very many original and " important observations.

" I am, Dear Sir, your faithful Servant,

" Colonel Jeffreys." (Signed,) " B. C. BRODIE.

Letter from Dr. Watson.

From Dr. WATSON, F.R.S.

" 16, Henrietta Street, Cavendish Square,
" August 8th, 1855.

" Dear Sir,—It is now many years since I read Mr. Julius Jeffreys's Essay " on the ' Statics of the Chest,' but I well remember that I was very much " struck with the novelty and (as I thought,) the soundness of the views ad- " vocated in that work. I have had many other opportunities of judging of his " talents and labours; and I can say with perfect truth, that I have not known " a more remarkable example than your excellent brother presents of a constant " and successful devotion of a singularly inventive genius, and a thoroughly " practical mind to objects intimately connected with the convenience and wel- " fare of his fellow-men.

" I am, Dear Sir, yours faithfully,

" Lt. Colonel Jeffreys." (Signed) " THOMAS WATSON."

From Dr. PROUT, F. R. S.

Letter from Dr. Prout.

" Sackville Street, 10th July 1845.

" Dear Sir,—I read your book with great interest, and as one of the very " best I had ever met with on the subject.*

" In the last edition of my 'Bridgewater Treatise,' recently published, I have " referred to it as containing what I consider unanswerable arguments against " some of the views of Liebig, and other modern chemists, respecting the cause " and nature of animal heat, and against which I have always myself protested. " The phenomena of life cannot be explained by chemistry; and all attempts " hitherto made by mere chemists have failed and must continue to fail.

" I am sorry to hear that for the present you have turned your attention " from Physiological pursuits into another channel—a channel, however, no less " beneficial I trust to the human race.

" I feel much obliged and honoured by your attention in writing to me, and " trust at some future time to have the pleasure of a personal acquaintance.

" In quoting your authority in favour of my opinion I have done you no more " than justice. Chemistry is an admirable auxiliary to physiology, but it has " been recently carried to the most absurd lengths, and far beyond its legiti- " mate application.

" I remain, dear Sir, yours respectfully,
" Julius Jeffreys, Esq." (Signed) " WILLIAM PROUT."

* " Statics of the Human Chest, Animal Heat," &c.

From Sir H. HOLLAND, Bart., F. R. S.

From Sir H. Holland.

" Lower Brook Street, Feb. 13, 1843.

" My dear Sir,—I feel much obliged to you for the kindness you have shewn, " in sending me your work on " The Statics of the Chest," etc., and I would " thank you also for the letter accompanying it.

" I began by reading the Appendix, and I may tell you in good faith that I am " exceedingly pleased with your criticisms on Liebig; the more so, perhaps, be- " cause many of the objections you have so lucidly stated had occurred to my own " mind, and led me to doubt the stability of that strong impression which has " been made upon the medical world of the time being. Much deduction from, " or modification of his doctrines must be made before they can stand " thoroughly good; and your criticisms will much aid to this object.

" I have not read more than a part of the work itself; but quite enough to " appreciate its value.

" Ever, my dear Sir, yours very truly,
" J. Jeffreys, Esq." (Signed) " H. HOLLAND."

From Dr. PARIS., V. P. R. S.

From Dr. Paris.

" My dear Sir,—I received, and have read your work with very great satis- " faction. Were I to express the amount of pleasure and instruction I have derived " from it, you would set me down as a flatterer; but believe me sincere when I " tell you that I think you have very ably and satisfactorily dispelled fallacies " that have long clouded very important points in physiology.

" Believe me, yours faithfully,
" Julius Jeffreys, Esq., (Signed) " J. A. PARIS."
Dover Street. March 21, 1843."

From PROFESSOR J. F. DANIELL., F. R. S.

From Professor Daniell.

" King's College, 11th Feb. 1843.

" My dear Sir,—Pray accept my best thanks for your kind present of your " book and the accompanying pamphlet. I shall read both with the greatest

"interest. I have already seen enough of the first to make me eager to peruse "the whole with as little delay as possible. My opinion exactly coincides with "yours.

"It always gives me pleasure to recollect that I was one of the early sub-"scribers of the testimonial to the merits of the Respirator. I have never ceased "since, pointing it out as one of the best illustrations of difficulties overcome "and skilful applications of scientific principles with which I am acquainted. "I know several persons who, with great reason, bless the inventor.

"Believe me, dear Sir,
"Very faithfully yours,

"Julius Jeffreys, Esq." "J. F. DANIELL."

From Dr. Mayo.

From Dr. MAYO.

"My dear Sir,—I have been very slow in acknowledging your book on 'The "Statics of the Chest,' etc.; and allow me to say that this has been in a "great measure the consequence of the richness and largeness of its contents. "I have read it through once, and am proceeding through it again. I wished "to digest it before I acknowledged it.

"Besides its great absolute merit, it is of extreme importance in modifying "the conclusions which Mr. Liebig considers himself to have arrived at.

"Believe me, with many thanks for your work,
"Yours very faithfully,

J. Jeffreys, Esq. (Signed) "H. MAYO."
Wimpole Street, March 14th.

"P.S.—I beg leave to add that I have testified my value for your book by "recommending it to my friends."

Temperance question.

To public and social questions my brother has devoted much time and anxious thoughts. Being struck with the appalling contrast between the state of sobriety even in heathen countries and what, in his labours amongst his poorer countrymen, he found to exist here, he took an active part in the temperance movement. Convinced that the prevalent opinion as to the necessity of an habitual employment of alcoholic fluids to support labour while productive of great evil, was based in physiological error, he obtained the signature of most of the leading members of the profession to the effect that such fluids are requisite neither to promote labour nor to maintain the ordinary health of man, however requisite for the enfeebled. This document has proved of great value to the cause, more than a million copies of it having been printed in this country and America.

Anti-Opium Society and China War.

His acquaintance from of old with the opium question also led him to join a benevolent body of men, chiefly influential Quakers, in the Anti-Opium Society, and he published in 1843 a pamphlet entitled "England and China," proving the iniquity of the China war. He also procured a professional opinion, widely signed by the most eminent men, against any but a medicinal use of opium, and denouncing altogether any dietetic or luxurious use of it. And with much research he collected evidence from China against its effects. Of this opinion and evidence the Earl of Shaftesbury, then Lord Ashley, made much use in an important

resolution he moved in the House of Commons during the China war, with so much feeling and eloquence, that, in the state of the House at the time, he might have carried it against the Government, had he not considered it right to yield to Sir Robert Peel's earnest exhortation that he would not embarrass them.

Labourers' Friend Society. A Society presided over with solicitous care by Lord Shaftesbury, and meriting universal support.

When resident in London my brother was on the Committee of the Labourers' Friend Society, and of the Distressed Needlewomen's, until it fell to his lot to discover the irregular manner in which the latter was being conducted. Its patron, the Earl of Shaftesbury (then Lord Ashley), the Honorable William Cowper, himself and others of the Committee, withdrew from it.

Experiment proving the solubility of Silica.

Besides the above writings, my brother's smaller publications and communications to societies and journals have been various. In 1838 he presented a short paper to the Royal Society, and in 1840 to the British Association for the Advancement of Science, on the solubility of Silica in water at very high temperatures, proved by an extensive experiment made by him in India, in which silicious minerals were copiously *dissolved* and *volatilized* in *steam* at a white heat—a fact bearing with force on geological evidence, and referred to as such by the late Dr. Mantell.

Experiment on the comparative size of liquid and gaseous particles.

In the London Philosophical Journal is a paper by him on the exosmosis of liquid and gaseous particles, detailing certain curious experiments, tending to prove the magnitude of gaseous particles to be greater than of liquid. The Medical Gazette of 1838, and of 1842, contains two series of papers by him, one series, on Warmth and Ventilation, and the other on Respiration, and the Atmospheric Treatment of the Lungs and Skin.

Pamphlets.

Feeling earnestly on the moral and religious bearing of certain public questions, he has published anonymously, and circulated widely at his own expense, pamphlets on "The Religious Question of Teetotalism," on "The Dissenters' Chapels Bill," on "The China War," and on "The Main Question for Church Laymen." This last however bears his name, and on "The loss of life at sea, through the inefficiency of ships boats."

Pamphlets. Invention of new boat pendants and clearing apparatus.

In 1851, on the occasion of the various deplorable accidents at sea, from the defective tackle of ship's boats, in which there was a repeated loss of many lives, he undertook, after having long hoped that some improvement would be made in ship's boats, from the time he had witnessed an accident on a voyage to India, to invent an apparatus to be easy of construction, cheap and manageable, which could not get out of order, and which should meet every requirement *in both the hoisting and lowering of boats.*

Successful trial of the above.

The equitable right to this invention he handed over to the Shipwrecked Fishermen and Mariners' Society, but took no patent for it. A large working model of it was exhibited at one of the soirees of the President of the Royal Society, Lord Rosse, and at the Royal Institution. With but a few exceptions it has been

greatly approved by naval officers. In 1853 he took the model, when on a tour to North Wales, to Liverpool, where it attracted much attention. Messrs. Jones and Palmer, the spirited and humane owners of many emigrant ships, immediately adopted it for the life boat of a large vessel, the "Goldfinder." Its action surpassed the expectation even of those most favourable to the plan, and led to the following testimonials being readily given by gentlemen of the longest nautical experience.

Letter from MessrsJones &c.

From Messrs. JONES, PALMER, & CO.

"Exchange Buildings,
"Liverpool, 28th July, 1853.

"Julius Jeffreys, Esq., F.R.S.

"Dear Sir,—We have great pleasure in giving our testimony to the "efficiency of your apparatus for hoisting and lowering ships' boats, which has "been fitted on board our ship *Goldfinder*, and has received the approbation of "all practical men who have seen it tried. It accomplishes, in the most perfect "manner we have seen, the two great requisites of lowering both ends of a "boat by means of one rope; and of detaching both ends of the boat by letting "go one lanyard.

"A remarkable illustration of the latter was given, when the *Goldfinder's* "life boat with fifteen people in her, was purposely detached in a moment, from "the apparatus when *four feet from the water*, and allowed to fall that distance "without inconveniencing those in her, or shipping any water.

"We hope shortly to hear of the plan being adopted, both in Her "Majesty's and in all passenger ships.

"We remain, dear Sir,
"Yours very truly and obliged,
(Signed,) "JONES, PALMER, & CO."

From Capt. Schomberg, R.N.

From CAPTAIN SCHOMBERG, R.N., Government Emigration Agent.

"Government Emigration Office,
"Liverpool, July 24th.

"Dear Sir,—Having observed on board the *Goldfinder*, passenger ship, "from this port, a very clever and ingenious plan of lowering and hoisting "quarter boats up, as also a very simple means of the boat escaping from the "Hoisting Apparatus, or Pendant, I beg to express to you the high opinion I "hold of such a valuable invention. It appeared to me to be equally applicable "to large or small means! In a merchant ship, the fall can be brought to the "capstan; in a ship of war, it can be used in the usual manner by hand. It "would enable a ship of the line to carry a heavier boat than is now carried, "having the lowering in such perfect control; and to sum up the whole thing, "I think it well worthy of practical use.

"Believe me, dear Sir,
"To remain most faithfully,
(Signed) "CHARLES F. SCHOMBERG, Captain R. N."

"Julius Jeffreys, Esq."

From Lieut. Wm. Lord, R.N.

From LIEUT. WM. LORD, R.N., Marine Surveyor, Liverpool.

"Marine Surveyor's Office,
"Liverpool, July 22nd, 1853.

"To J. Jeffreys, Esq.

"Sir,—Having witnessed the trial of your invention for the hoisting and "lowering of ships' boats, as fitted on board the Australian packet ship "*Goldfinder*, at this port, I have much pleasure in bearing testimony to the "simplicity and efficiency of your apparatus, which is certainly superior to any

" I have previously seen ; and if generally adopted, will I have no doubt, be the " means of averting many of those fatal accidents which occur in the hoisting " and lowering of ships' boats in cases of emergency.

" Yours obediently,

" (Signed,) WM. LORD, Lieut. R.N.,

" Marine Surveyor."

From CAPTAIN COOK, Superintendent of Pilots, Liverpool. From Capt. Cook.

" Superintendent of Pilots' Office,

" Liverpool, 13th July, 1853.

" Julius Jeffreys, Esq.

" Sir,—I have had the pleasure to witness several trials of your invention " for lowering and hoisting boats on board the Australian packet ship, *Goldfinder*, " now fitting out at this port. It surpasses anything of the sort I have ever " seen. Its simplicity in operation is well suited for the purpose *of saving pas-* " *sengers or landing troops*, by enabling the boat to be fully loaded whilst on a " level with the rail; and without a reference to the inequality of weight, " to be lowered parallel and immediately released from the tackling. Had this " plan been fixed on board several unfortunate steamers, many lives would have " been saved. I consider the public are much indebted to you for this valuable, " cheap, and simple invention.

" I have the honour to be, Sir,

" Your obedient Servant,

(Signed,) " JOS. COOK,

" Superintendent of Pilots, port of Liverpool."

From CAPTAIN W. A. MITCHELL, From Capt. Mitchell.

Surveyor for the Liverpool Underwriters' Association. Surveyors Certificate

" Underwriters' Rooms,

" Liverpool, 20th July, 1853.

" The undersigned witnessed the working of your invention, for lower- " ing and hoisting of boats, on board the ship *Goldfinder*, lying in the Princes " Dock, and my opinion is, that it surpasses any invention for lowering and " hoisting of boats that ever came under my notice. The simplicity of con- " necting and disconnecting is such, that under any circumstances, in a rough " sea, with common caution, no accident in my opinion could occur.

" W. A. MITCHELL,

" Surveyor for the Liverpool Underwriters' Association."

From Mr. JOHN CRAWFORD. From Mr. Crawford.

" Liverpool, 23rd July, 1853.

" Sir,—I have inspected your invention for hoisting and lowering boats " fitted on board the ship *Goldfinder*, of this port, now bound to Australia, and " admire it for its simplicity and efficiency of connecting and disconnecting " the boat, in any weather. It is the best plan that has come under my notice " for the safety of life.

" I am, Sir,

" Your obedient servant,

" JOHN CRAWFORD

" Overlooker for Messrs. Taylor, Potter, and Co."

" Julius Jeffreys, Esq."

The attention of the Admiralty having been again called to this decisive trial, they authorised the adapting of the plan to a man-of-war's boat, but the active preparations for war commenced, Trial of the plan ordered by the Admiralty.

and the execution of the order was suspended *sine die*. In the mean time *many* sad accidents connected with the public service have been published, and others doubtless have occurred, from defective boat-tackle. Amongst them, that to the *Europa*, in which the gallant Colonel Moore, and many of his brave soldiers perished, as well as some of the crew. Had that ship been fitted with my brother's apparatus, it is difficult to believe that the whole of the lives might not have been saved with certainty. In the mean time, also, the *Goldfinder* has returned from Australia, and her owners have been so well pleased with the apparatus, as to have fitted another ship with it. My nephews, the Messrs. Nicol, have also fitted it to a boat of their screw steamer *Army and Navy*, now in the Black Sea, and state that they have already, on different occasions, saved lives from accidents they have witnessed, but unconnected with their own ship, which must have perished had they depended on the resources of the vessels concerned.

Invention of the deflecting & reflecting grate.

Two winters ago my brother contrived a grate for domestic use (with the view of avoiding the domestic smoke of towns), on the principle of changing the usual upward current, to

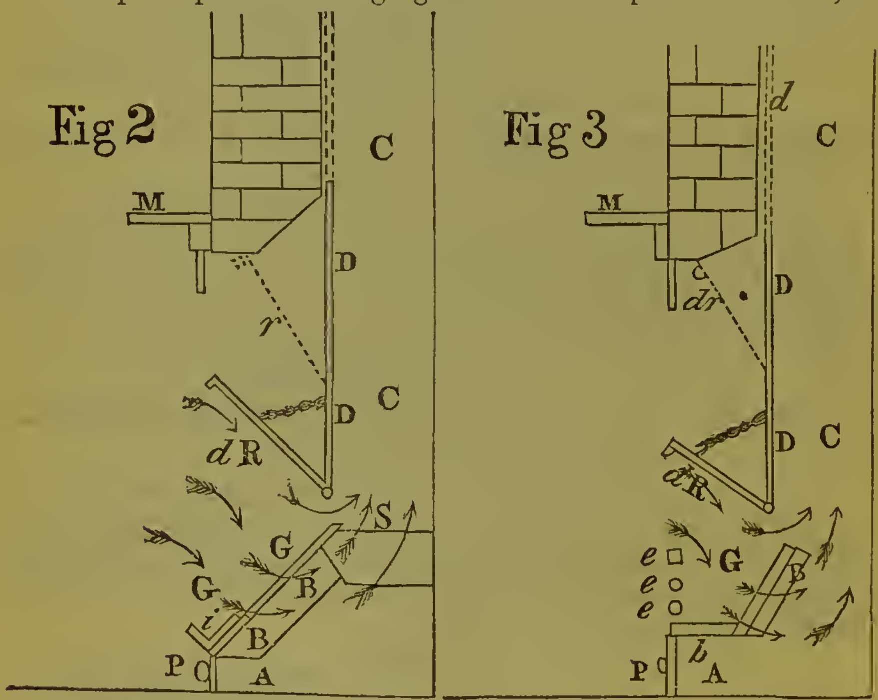



Fig. II. and III.—Vertical Cross Section of the Deflecting and Reflecting Grate.

A.—Ash Pit.
BB.—Fire Back, forming in Fig. II. the bottom also.
b Fig. III.—Bottom Grate.
CC.—Chimney.
DD.—Diaphragm, or partition.
d R.—The Deflecting Reflector.
ee.—Front Bars.
G.—Grate.
M.—Mantel Shelf.
P.—Ash Pit cover, always carefully closed, except to remove ashes.

one backward and downward, through the fuel, so as to transfer the active combustion from the bottom to the top and front, the surfaces towards the apartment; and then to reflect into the room by a steel, or planished tin mirror, such of the brilliancy thus excited as would otherwise shine to waste up the chimney. Nothing can exceed the brilliancy and effect of this fire.*

In Fig. II., the principle of this grate is fully developed. The chimney way is closed by a sliding Diaphragm, or "blower," DD. set far back, and carrying at its lower edge, an inclined plate, R. hinged on to it, that the angle of inclination may be varied. This plate turns the current down through the fuel, lying in the shallow inclined grate G. By facing the Deflector with a burnished plate, it becomes also a reflector. It can be depressed, or raised up to the position of the dotted lines, d, r, by winding up the diaphragm, and thus the force of the draught is determined.

In Fig. III., the principle is adapted to existing grates, with the view of avoiding expense and of offending against accustomed forms as little as possible. In this form it is particularly suited for the combustion of smokeless fuel, as coke, &c. But if the first form, Fig. II., has the portion i. of the grate closed at bottom, then, by pushing up the bright fuel with a shovel made for the purpose, *common coal* may be laid on the part i. Its smoke sweeping over and through the bright fuel above it at G. will be nearly all consumed.

But to get rid, with certainty, of all domestic smoke of towns no plan can equal the consumption of absolutely smokeless fuel. My brother therefore, having by trial satisfied himself that the bituminous part of coal is of little heating value in a *radiant* or house fire, proposed that the coal should be coked at the pits' mouth, and the heat evolved in the process be employed to ripen fruits in hot houses, for sale to the community generally; so that London smoke instead of fouling the atmosphere, might henceforth be represented in the metropolis, by an abundance of grateful and wholesome fruits.

In the month of November last my brother submitted to the Duke of Newcastle a plan (based on a large erection he made in India) for constructing barracks for soldiers in the Crimea, promising to be at once very easy and cheap in construction, and very warm for winter and cool for summer; and also proof against accidental conflagration. The proposal was politely acknowledged, and referred to the Ordnance Department; but not adopted. Proposal of temporary Barracks for the Crimea.

In January last he laid before the Admiralty plans for rendering existing ships of war fire-proof; for constructing new ships of war and floating batteries on a principle apparently more Plans for ships of war and floating batteries.

* It has been my brother's purpose, as soon as steps can be taken for the introduction of this grate, to transfer the property to a medical charity, the objects of which he has much desired to promote, and for which purpose the patent has been secured.

suited to the exigencies of the times, so as to be indestructible by fire, and for giving a peculiar form to batteries to ensure their not *taking* ground on running against sand or shingle banks.

The great national importance of the objects sought in this communication to the Admiralty, urges me to step beyond my limits in this instance, and to insert it at length, as it afterwards appeared in the "Journal of the Society of Arts," of the 16th of March.

ON THE CONSTRUCTION OF SHIPS OF WAR.

"To the Editor,

"Sir,—The national importance of the subject prompted the drawing up of the following paper of suggestions for improving the efficiency of our ships of war, in January last, not indeed with any assurance that the Admiralty could be moved by an individual effort to so progressive a step, but under the impression that it behoves every subject of the state to do what in him lies to strengthen her efforts at the present crisis, whatever may be his opinion as to the original expediency of the struggle she is engaged in.

"Though more than one engineer of the first ability has expressed a very favourable opinion of certain of these suggestions, your correspondent is quite prepared for various grave objections being raised against them. To such all efforts after important ends must be obnoxious in this our sublunary state, where every action of our lives is but a choice of evils. Any plan promising great advantage, free of all disadvantages, can find no practical realisation in this our lower world.

"Thus the stem of a floating battery formed as in Fig. 3 would doubtless diminish its speed; but then, speed is of small moment for it in comparison with security against the possibility of the vessel's grounding. Again, it may be questioned if the stem could be given sufficient strength to act as a kind of plough-share over so large an area of sand, even though the vessel should be proceeding cautiously; but your correspondent has, in long voyages up and down the river Ganges, so repeatedly watched the different effects of shoaling against sands on large boats of various forms of stem, that he is persuaded a heavy flat-bottom vessel could, by a proper construction and strutting of the stem, be better prepared to receive the shock of a cautious speed end on, than the strain of rubbing over gravel and riding up an incline till she was half out of water. But, whatever the strain it involved, the object sought by the former construction—a security against the possibility of lying helplessly grounded in shoal water under the fire of a battery—is one of too great importance to be relinquished until the difficulties, which an unaccustomed form may suggest, have been demonstrated insuperable, either upon constructive principle or by actual trial.

"Nor is a security against getting aground the only advantage of such a construction. A vessel so formed could work its way, by repeated impulses, from one deep channel to another, through bars at the mouths of rivers and through shoals between channels, even where there was not over the bar or shoal a depth of water equal to, perhaps, half the vessel's draught. In Asiatic rivers, a fleet of boats, some of them carrying from fifty to one hundred tons of produce, and drawing four feet of water, will be worked through a long and firm sand, over which there are not two feet of water, by mere manual labour; each vessel in turn receiving the aid of two or three crews besides its own, who stand around it in the water, and simultaneously jerk the vessel forwards, so as to agitate the sand into a semi-fluid state.

"The question, however, of paramount importance is the protection of ships-of-war from conflagration; and it is the chief object of this paper.

"The structure (Fig. 1.) proposed as the fabric for future vessels would obviously possess this advantage of incombustibility in an especial degree,

not form the strength of the fabric of batteries, nor guard them from instant conflagration by missiles projected through their port-holes, and conveying fire to exposed surfaces, while they must seriously increase the draught of the vessel. Supposing the plating over the deck to render an equal weight below necessary as ballast, it would add altogether *five-and-a-half feet* to the draught!

"As to the form of a floating battery.—It is desirable that it should be so constructed as not only to draw as little water as practicable, but also, if possible, to suffer no injury on running aground upon any surface but solid rock, and to have a tendency to float off by itself, or easily by the aid of its engines. A stem formed like Fig. 3, with a stout recurved foot at A, of massive iron, and a perfectly flat bottom, would not, on striking, ride up on to a sand or shingle bank, but would plough for the vessel a level bed, over which she would float

Fig. 3.


if trimmed slightly down by the head, while the earth heaped up ahead would help to push her off as soon as her momentum ceased, or, if desired, she might, by returning with repeated moderate impulses, cut her way through a bank of sand to a deeper channel.

"By such a construction the whole force of the blow would be thrown lengthways against the bottom, which, if massive and properly framed to the stem, and embraced by iron arms, projecting laterally from the iron foot ahead, should not suffer from the shock of any cautious motion against it, end on; whereas a strain to a vessel riding up on a bank might be much greater, while it would be scarcely possible to get a vessel of immense weight off again when under fire.

"In operations against land batteries, the effectiveness of a floating battery would be greatly increased by a freedom from all danger in shoal water, enabling it to operate fearlessly in any position."

That some of these plans must in time be adopted, I think there can hardly be a doubt. In favour of some of them, one of the highest opinions amongst naval engineers has been decidedly expressed.

'roposed nprove- ients in )rdnance.

In January he also laid before the Board of Ordnance certain remarks upon the construction of elongated projectiles, compounded of the cone and cylinder (for great and small arms), which should travel steadily point on, and concentrate the momentum in a point of hard steel, as the most effective weapon for splitting stone walls; also, upon what he termed the "cradling" of the mouth of guns (large and small) to preserve the direction of the shot from disturbance by any side blast of the powder on its escape from the mouth of the piece. In all these pro-

iron ships, form the exterior surface. Let from 6 inches to a foot of wood filling-in *b* 1 (formed of any tough old timber or cubical blocks of wood, with cement to fill up all spaces) come next; then a table, *a* II., of sheets of $\frac{1}{4}$ inch iron be nailed, with long spiked nails, against this wood filling in; the edges of the sheets being nailed over each other. Let a second layer *b* II., of such wood-work follow, and a third table of iron, *a* III., be nailed on to it, and so on, until the wall had the determined thickness, from one layer of wood enclosed in iron upwards to any extent required.

"Then let bolts of $1\frac{1}{2}$ to 2 inch round iron, pass through the whole, keying up each table of iron, and binding the whole together by screw nuts; there might be one such bolt to every square yard of surface.

"Not only would such a fabric for ships' walls possess prodigious strength, probably surpassing *for them* the tubular principle of bridges, inasmuch as it would be solidly firm in *every* direction against the countless strains in floating vessels; so that with proper decking of a like kind, and truss-framing, vessels of gigantic dimensions might be made, if desired; but it would remove all danger of conflagration. It would, likewise, receive solid shot in the very best way. The sheet-iron tables, if duly proportioned in thickness to the wood supporting them, would be punched into the wood behind them, as into a die, as at *g g*, the shot driving on the cup-like pieces before it, until its momentum was exhausted, which cups would, indeed, guard the wood before the shot from singeing, though this is of minor importance.

"Such a fabric might be riddled by shot, like a colander, before its strength was materially impaired, and it could be readily repaired by driving plugs into the shot-holes, and plating over the outermost table of iron and the innermost also, where the shot went clear through the wall.

"It is, perhaps, not too much to say, that a large ship thus constructed would not be more costly per ton measurement than ordinary ships of war. While armed with suitable missiles of conflagration, [conveying solid and liquid fire,] it might set a whole navy of ordinary ships at defiance, and any that approached it destructively on fire in a few minutes.

"A floating battery fabricated in the same way, but more massively still, and of the form described below, might, if armed with a missile of another character, be enabled to hew down stone fortresses impregnable by round shot.

"The writer has regretted that the experimental iron ships were so hastily denounced. They only required to be banked up with wood against the metal, and this again lined with thinner iron, studded to it with nails, to make them, perhaps, the most serviceable vessels at present afloat. The wood would have served as a die, causing the outer plating of iron to be punched into it by round shot, instead of being extensively crushed in and torn.

"The time has surely come when future ships of war must be constructed in a totally different manner from the present, and when existing ships must have every air passage in their walls—every feeder of conflagration—stuffed with cement, and every wooden surface cut off from the play of oxygen by plating with metal.

## A Word on Floating Batteries.

Floating Batteries.

"Plates of solid iron four-and-a-half or five inches thick overlying wood are reported to stop dead the largest round shot, which after, causing considerable indentation, *fly to pieces* against them. Would it not be prudent to try the effect of *wrought* iron shot, (easily made by compression,) the momentum of which cannot be thus instantaneously destroyed by diffraction, before trusting implicitly to even five inch plates? If the plates are still sufficiently resistant, their object will be secured for floating batteries; but for ships of war generally they would, of course, be inapplicable, and, as said to be employed, they do

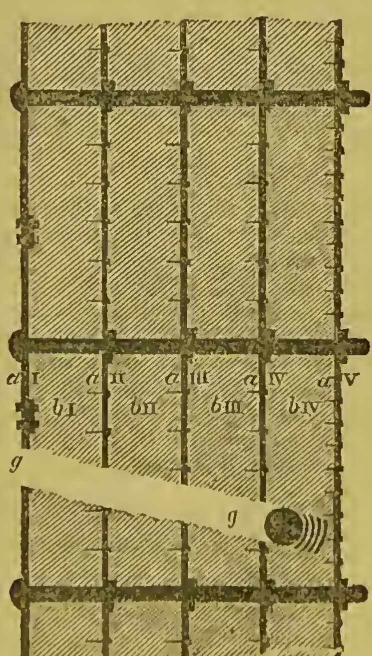
" A shot, however intensely heated, penetrating and even lodging itself in wood properly coated from the access of air, could only reduce two or three inches of wood around it into charcoal, which, without air, would form a bed indestructible by any heat known, and eminently non-conducting, in which the shot might be permitted to lie for any length of time. As to the hole made by the shot, combustion could no more thrive at the bottom of it that in the socket of a deep candlestick in which a light had burnt down ; and the hole could always be stopped for the time with clay or cement. The oxygen in the woody fibre itself, only suffices to blow off in union with its hydrogen as steam, or with a little carbon also, as some pyroligneous compounds. The carbonaceous mass of the wood would assuredly remain unconsumed, so long as air had on free access to it. [It would be equally proof against a liquid however spontaneously combustible.] There is, perhaps, nothing to prevent ships on service from being subjected to this cementing and sheathing process by the carpenters and engineers on board, whenever the weather is fine ; planks at different levels being removed, and liquid concreting cement being poured into all crevices to fill them up ; the surfaces might then be well cased with metal from the water's edge, as well as all interior surfaces.

" The writer is next led to repeat a proposal for the construction of ships' walls in future, which he made last year to an able officer connected with the service.

" For the main substance of ships' walls, woody fibre is, perhaps, the best material. But mechanical and economical principles indicate that it should be employed in the walls, not actively as their framework, but what may be termed passively, rather ; as a massive support to the material of active strength, and as a tough bed for cushioning shot—destroying gradually that momentum which cannot be instantaneously annihilated.

" The great cohesive power of iron points it out as the material for the active strength of the walls. But in *ships*, at least, to give it a shot-proof thickness, cannot be thought of. Let an outer table, or wall of iron, *a* 1, Fig. I, say from a quarter to one-third of an inch thick, of sheets rivetted together as in

Fig. 1.



together with that of great mechanical strength, and of rendering the timber of old ships, if sound, and merely cubical blocks of wood, almost equally servicable for new vessels with the primest timber.

"It is in no warlike spirit that these proposals have been tendered, but, under the conviction that, so long as a spirit of ambition, vain glory, and aggression, shall continue implanted in man's nature, it is necessary that this country (while more earnest than hitherto in surpressing these evil emotions in herself,) should possess a defensive navy of commanding strength ; and it is not in a dogmatic spirit, but a suggestive and deferential one, that this paper is submitted to the attention of the Members of the Society of Arts, through its ably-conducted Journal, with the view of inviting to the questions proposed the inventive and constructive talent which abounds amongst them, and which, if duly encouraged by those who have assumed charge of the public interests, would, doubtless, be successfully exerted for the nation's good.

I am, Sir, your obedient Servant,

Kingston Hill, Surrey, Feb. 28, 1855. JULIUS JEFFREYS."

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"REMARKS ON SHIPS OF WAR AND FLOATING BATTERIES.

"In these days of incandescent projectiles, combustible ships of war promise to become about as serviceable as would be combustible fire-places.

"Not only do red-hot shot imperil the wooden walls of England, but it would be easy to suggest a more dangerous missile of conflagration still, from the action of which, probably, nothing could save ships, as at present built, from suffering destruction. [Hollow shot may be filled with naphtha, or like fluid, and fired (with two fuses in opposite holes,) so as to lodge in a ship's side. On the fuses burning down, the liquid would run out on fire. Water applied would only aggravate the effect, by floating onward the burning oil. Nothing could save ships, as at present built, from destruction by such liquid fire running down through all air-spaces. The addition of sulphur and phosphorus would probably render the fluid spontaneously combustible on exposure to air; but this would scarcely be necessary, as the fuses would be certain to set it on fire.]*

"Were all the air-spaces in ships' walls as necessary as is commonly imagined for retarding decay, they are, in these days of projectile heat, so imminently dangerous as feeders of combustion, that it is a question whether every ship in the navy ought not to be immediately uncased sufficiently for all these interstices to be filled up thoroughly with cement. But this cementing would also put an end to that infiltration of air and moisture which is the real cause of rotting, and which is now rudely remedied by a rush of air. If air were really needful to prevent rotting, the heart of every thick timber to which air has no access would be the first part, instead of the last, to rot. On every account, then, air should be shut out from every part of the *fabric* of a ship.

"Having filled up all interstices, the next point is to allow no wooden surfaces to be exposed, but to coat them everywhere with sheet-metal, say copper on the outside and iron† on the inside of the walls, and decks,‡ and iron round beams, &c. Quite thin metal would answer, if studded over with nails.

* This portion in brackets is inserted from my brother's communication to the Admiralty, in January. It was purposely omitted in the *published* paper for obvious reasons, but, as in the recent experiments of Captain Disney, detailed in *The Times*, a shell very similar in character is described, there is no longer any reason for surpressing the suggestion. Though it appears to have been first officially made by my brother, it is of little importance to whom the thought may have first occurred. That it should have occurred separately to two or three persons, unknown to each other, gives it an importance, to neglect which may lead to results of a most serious character; whereas, an engineer of the first authority has expressed his opinion that my brother's plans would render ships proof against all such conflagrating agents; so long as their fabric held together.

† Or iron on the outside of the ship above water would answer if well painted over, though no galvanic action between the two metals is to be feared through the massive and dry walls.

‡ Over the metal casing of decks thin planks of hard wood might be nailed down, to keep the feet of the crew from the slippery and conducting metal. This planking, on taking fire, could burn but feebly, if at all, over metal, and could communicate no combustion through it.

posals relating to the public service, my brother had no personal or pecuniary interest whatever; and has considered them justified by a desire, felt in common with every one, for the preservation of our forces, and for an early and successful termination of the war, without any reference to the duty or expediency of engaging in it, or in most of our other great wars.

His attention has been recently given to inventions for personal, and for domestic purposes, which promise to be of much use, and will be introduced by manufacturers. Various other inventions.

Connected with improvements in the useful arts, &c., my brother has made many successful inventions in machinery, in apparatus, and in chemical processes, to which I have not referred. A full description of his experiments connected with the generating and refining of one important staple of Indian produce, salt-petre, alone, and the great scale upon which he reduced into practice with entire success, a novel method of refining by one operation its crudest into its purest forms, together with a description of the construction of the extensive works for the purpose, full of peculiar apparatus (and that in a rude and distant province wholly unaided by European engineering and manufacturing art), would itself fill a pamphlet of considerable bulk. Yet this was by no means his chief effort in the improvement of the arts and developing of the resources of India.* During the whole time of such occupations, he was noting phenomena and drawing inferences of a purely philosophical character, as his writings abundantly prove. That his labours have not been made more public, is due to his very retired and unambitious habits. For the same reasons several of his inventions though perfectly successful, have remained unnoticed; a fact which I think it right to mention, on account of the utility and importance of their objects; while the limited space of this biographical notice, does not admit of their being described, for which drawings would be necessary.

* My brother concluded his papers on India referred to in p. 11, with the following emphatic aspiration for the improvement of its people and its resources; to which he had so successfully devoted his efforts.

"It is to be feared that at present, no considerable part of the revenues of India is likely to be devoted to the purposes recommended,—to commencing that movement, to which alone we can look for any advancement of the people towards a state of prosperity, and any increase in the revenues of the government:—not a movement, indeed, of armies for the territorial enlargement of British India, but of mind for the enlargement of her resources:—not an increase of superficies, but of solidity:—not an acquisition of more land, but a deeper cultivation of that we possess; a drawing of more produce from the surface of India and more minerals from its bowels:—not a heaping of people upon people, but a judicious distribution of those we have; a transfer of millions at present jammed in the agrarian crowd to all other pursuits of civilized men; a portion of them to the service of the state."

The following learned Societies have done him the honour of electing him into fellowship with them :—

The Royal Society in 1840.
The Royal Medical and Chirurgical Society in 1838.
The Statistical Society in 1845.
The Geological Society in 1846.
The Royal Institution in 1838.

Concluding remarks.

In concluding this brief sketch of my brother's pursuits, I have to express a hope that I shall not have appeared to the reader, who has done me the favour of perusing it, to have allowed my partiality as a brother to draw from me any eulogistic expressions not fully justified by the numerous facts I have adduced, and by the many flattering testimonials from the first authorities in the various fields of research and effort to which my brother's attention has been directed. They who know how much care and thought are requisite for discovering in the well-trod paths of any single science matter at once original and sound, and they who know how much of thought, time and labour any single invention in the field of practical science will consume, first in its conception and then in its realization in an efficient and useful form, will best appreciate the labours of which the preceding pages afford but a very imperfect outline.

EDWARD JEFFREYS,
LIEUTENANT-COLONEL,
Bengal Army.

Kingston,
August, 1855.

J. & I. Tirebuck, Printers and Lithographers, Monkwell Street, City.

5

DESCRIPTION OF THE

# VENTILATING FAN

AT THE

## ABERCARN COLLIERIES,

BY

EBENEZER ROGERS, MEM. INST. M.E., F.G.S., &c.

---

EXCERPT MINUTES OF PROCEEDINGS

OF THE

## MEETING OF THE

## INSTITUTION OF MECHANICAL ENGINEERS,

AT BIRMINGHAM, 5TH NOVEMBER, 1856.

SAMPSON LLOYD, Esq.,

IN THE CHAIR.

---

BY PERMISSION OF THE COUNCIL.

---

BIRMINGHAM:
PRINTED AT M. BILLING'S STEAM-PRESS OFFICES, LIVERY STREET.

1857.

## TABLE II.

*Table illustrating a Mine Explosion.*

| BEFORE EXPLOSION. | | AFTER EXPLOSION. | | | |
|---|---|---|---|---|---|
| 5 vols. of Carburetted Hydrogen. $5\ CH_2$ | 40 vols. of Atmospheric Air. $8\ O + 32\ N$ | 2 vols. of Vapour of Carbon. 2 C | 3 vols. of Carbonic Acid Gas. $3\ CO_2$ | 10 vols. of Vapour of Water. 10 HO | 32 vols. of Nitrogen Gas. 32 N |
| C 1 vol. | | C 1 vol. | | | |
| C 1 vol. | | C 1 vol. | | | |
| C 1 vol. | O $\frac{1}{2}$ vol.<br>O $\frac{1}{2}$ vol. | | $CO_2$ 1 vol. | | |
| C 1 vol. | O $\frac{1}{2}$ vol.<br>O $\frac{1}{2}$ vol. | | $CO_2$ 1 vol. | | |
| C 1 vol. | O $\frac{1}{2}$ vol.<br>O $\frac{1}{2}$ vol. | | $CO_2$ 1 vol. | | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| H 1 vol. | O $\frac{1}{2}$ vol. | | | HO 1 vol. | |
| | N 32 vols. | | | | N 32 vols. |

The chemical equivalent of oxygen by volume, or the combining volume of oxygen, being a half-vol., the 8 vols. of oxygen which are in mechanical mixture in the air before explosion represent the 16 equivalents or 16 half-vols. which are in chemical combination with the carbon and hydrogen after explosion.

The CHAIRMAN thought a more interesting and important paper could not have been brought before the Institution, for every one acquainted with the working of collieries must be aware of the great value of thoroughly efficient ventilation, and the danger and serious risk of life attending any imperfection in the system. Only a few months previously an explosion had occurred in Wales, by which more than a hundred persons had been killed in one pit, showing the necessity of adopting some efficient system of ventilation, that would not be liable to derangement from accidental causes; and the method now described was certainly a very simple and mechanical way of accomplishing this object. Several attempts at mechanical ventilation had been made previously, but did not appear to have met with much success in actual adoption: mechanical means had been tried, he believed, more in Wales than elsewhere, because the coal in that district contained such a large proportion of explosive compounds. He enquired what were the essential points of difference in the previous methods from the one now described.

Mr. ROGERS replied that there was nothing new in the principle of ventilation by purely mechanical means; the same principle had been in use centuries ago on the continent, although of comparatively recent introduction into this country. The old German miners had used an inverted tub, placed in water, and worked up and down by a lever, with an air valve at the top opening inwards, the fresh air being alternately drawn into the tub and expelled along an air main conducting it into the workings. This rude contrivance had been recently improved and the plan carried out on a large scale in Struve's ventilator, in which the inverted air vessels were like large gasometers; but the apparatus was expensive and proved troublesome in working. Rotary ventilators, acting on the principle of the screw, had been tried in some cases; and the fan had also been applied, but without success, in consequence, he considered, of a want of mechanical knowledge on the part of those who had sought to adopt this method of ventilation. The need of sound mechanical applications in carrying out improvements of this nature formed his principal reason for bringing the present subject before the Institution, with the view of drawing attention to its importance.

The fan at Abercarn had proved completely successful, and he was not aware that any really effective machine had been produced previously; but the subsequent one at Skiar Spring Colliery was still better, and experience would no doubt lead to yet farther improvements, particularly in a still

farther increase of the diameter of the fan. In some of the early attempts the air was forced down the pit by a blowing fan, which was beginning at the wrong end of the process; and another mistake that had been made was that the area of the branch air passages was too small at the point of taking off the air, causing a serious waste of power and a check to the current in passing the contracted parts. In Mr. Nasmyth's fan the simple direct-acting engine was an important feature, together with the compact arrangement of the machinery, requiring no foundation but the fan case itself, and giving no trouble in keeping it in repair. The engine was capable of driving the fan at 100 to 120 revolutions per minute if requisite in an emergency, but the ordinary speed was 50 or 60 revolutions per minute. This fan had been two years in constant work, without requiring any repair, and appeared in as good order now as at first starting; the cost of working, as compared with the old imperfect furnace ventilation, was remarkably small, the fan saving certainly 9-10ths of the fuel consumed by the ordinary ventilating furnace. The efficiency of the air valve covering the top of the pit was an unexpected result, and simplified the construction of the apparatus considerably. It had been thought originally that two air valves would be required, to prevent loss by drawing in air direct from the top of the pit, and double valves had consequently been provided; but this provision was found unnecessary, as it appeared that a column of air of so great length, extending over 12 or 15 miles through the mine, when once set in motion, was not perceptibly affected by a slight check at the end of its course, and was not disturbed by the passage of the cage in and out of the mouth of the pit; the simple flat door at the top accordingly answered the purpose completely. In the erection of subsequent fans the construction might be farther simplified by the substitution of thin stone or brick walls on each side of the fan, in place of the present iron casing, with the advantage of cheapness and facility for renewal or repair.

The CHAIRMAN observed that the plan now described appeared to be far superior to the ordinary system of furnace ventilation, in which a large furnace was kept burning at the bottom of the shaft, so as to rarefy the air and make the requisite draught up the shaft to draw the current of air through the mine. Such a method was unavoidably attended with continual variations in the current of air through the workings, as the fires fluctuated according to the brightness or dullness of burning at different times, and the ventilation was directly affected by irregularities in keeping up the

fires and variations in the state of the atmosphere. The use of jets of steam for ventilation, proposed by Mr. Gurney, had recently been in favour, the steam acting in the same manner as the blast in the chimney of a locomotive engine; he enquired what was the general result of this plan, and whether it was now in regular work.

Mr. Rogers thought the employment of steam jets must always be an imperfect and expensive mode of applying steam power for ventilation; it was much preferable to apply the steam direct to work a fan, by which means a low pressure of steam could be made fully available. He did not think the plan of steam jets was continued in practical use; one serious objection to it, that was experienced when tried on a large scale, was the constant shower of water caused by condensation, from the large quantity of steam thrown into the air shaft.

Mr. Hawkes asked what degree of vacuum in inches of water was obtained by the fan ventilation, and how the velocity of the air had been estimated. From $\frac{1}{2}$ inch to $\frac{3}{4}$ inch of water was, he had found, the ordinary vacuum obtained in stationary engine chimneys.

Mr. Rogers had found in his own experiments from $\frac{1}{2}$ inch to 1 inch of water pressure, according to the speed of the fan; he had tried the vacuum by means of a water gauge, and had also estimated the velocity of the air by Dr. Hutton's theoretical calculations. The results had been checked by Biram's and other anemometers, and had been found to agree very well. A third test had been tried by firing powder at measured distances in the workings by means of a voltaic battery at the surface, the time of passage of the powder smoke to the surface being noted by a watch.

Mr. Hawkes asked what amount of vacuum was obtained in the ordinary furnace ventilation of collieries.

The Chairman said that the information on this point was very imperfect, from the uncertainty about the experiments; he supposed the vacuum was generally below 1 inch of water, perhaps considerably less: but in large deep mines a vacuum of as much as 2 inches of water was sometimes required to overcome the resistance to the current in the workings.

Mr. Rogers remarked that there were several disturbing causes to be taken into consideration, and great precautions were necessary in ascertaining the vacuum correctly. The barometer showed 1 inch difference of height at the top and bottom of a deep shaft, such as that at Abercarn of

nearly 900 feet depth, where it stood at 29 inches at the top, while it showed 30 inches at the bottom. The particulars of the height of the barometer and difference of temperature had been noted in his experiments, and were given in the table appended to the paper, together with the degree of vacuum arising from the natural ventilation due to the difference of temperature, which amounted to about $\frac{1}{7}$ inch of water.

Mr. Shelley enquired whether the distance of the fan from the pit mouth and its relative position were material for its good working.

Mr. Rogers said the distance of the fan from the shaft was immaterial, provided that the air passage from the pit to the fan was of the full size, free from contractions or obstructions. All that appeared requisite was to make the fan large enough to have an ample margin of surplus power of ventilation, without requiring a high speed of working; and from the results of his experience he should certainly recommend in future a considerably larger size of fan, probably as large as 21 feet in diameter.

Mr. Hawkes mentioned that a species of fan for ventilation had been tried many years ago by Mr. Brunton, acting somewhat on the principle of a screw, to which allusion had been made; but he was not aware what results had been obtained with it. He remembered that Mr. Nasmyth had read a paper on the subject of ventilating fans at the meeting of the British Association at Ipswich several years ago, but thought the arrangement then proposed was different from that now described.

The Chairman asked what was the construction of the ventilating fan at Mr. Powell's colliery in South Wales, which was probably the one referred to as Mr. Brunton's, and whether it was at work now or had been given up.

Mr. Rogers replied that was the fan on Mr. Brunton's plan, and he remembered seeing it first put to work about nine years ago; it was a horizontal wheel about 9 feet diameter covering the top of the air shaft, with a large number of vanes set inclined like the vanes of a windmill or the blades of a screw; the air had access to the vanes on the underside, and was expelled from the upper side of the fan. The plan was found to be imperfect and unsatisfactory as a means of ventilation, and he believed it had been entirely abandoned. In the paper read before the British Association that had been referred to, Mr. Nasmyth proposed a fan only about $4\frac{1}{4}$ or $4\frac{1}{2}$ feet diameter, which was so small a size that it would not have at all answered the purpose. The large size of the present fan was

the most important feature in the improvement, by which indeed the practical difficulties had been overcome. The whole credit of the calculations and arrangements in the form of the present fan was due to Mr. Nasmyth, and they were founded on the results of his experience; there might no doubt be many modifications of the form and proportions of the different parts of the fan, but these did not appear to be material points, and the simple construction that had been described appeared practically as good as any. He might mention that the plan had been thrown open by Mr. Nasmyth for general use, without reserving any exclusive right in it.

Mr. Cochrane thought a great feature in the plan of fan ventilation was the simplicity of the apparatus, and the smallness of cost, and also the applicability to deep mines; the great freedom from risk of derangement was an essential point, removing the objection ordinarily urged against ventilation by mechanical means. Any plan which tended to preserve life was of great value, and the fan ventilation was certainly an important step in the right direction; great credit was due to Mr. Rogers for investigating the subject so completely, and making such a thorough practical trial of the plan. There was no doubt this fan was doing the work of ventilation admirably, and he thought surpassing all other plans, and it required only to be better known to be extensively adopted; they were greatly indebted to Mr. Nasmyth for effecting this valuable improvement in the mode of ventilating mines.

Mr. Rogers observed that the power of suddenly increasing the current of air through the workings in any emergency was a great advantage over the ordinary furnace ventilation, in which no such change was practicable. He was convinced that the majority of deaths from explosions resulted from the suffocating effects of the after damp, and not from injuries occasioned by the explosion itself; and in cases where men recovered after an explosion, it was observed that a quantity of black carbonaceous matter, or "coal dust" as it was termed by the miners, was first thrown off the lungs; this was the result of the deposition of carbon in the atmosphere that had been inhaled; for every 45 volumes of fire damp, which was a mixture of carburetted hydrogen and air, produced in the explosion 2 volumes of vapour of carbon, which was precipitated in the form of minute black flakes filling the air. In the case mentioned in the paper, the result of suddenly turning the steam full on to the engine of the fan was remarkable; an immense volume of air, probably 70000 or

80000 cubic feet per minute, instantly swept through the works like a hurricane, and carried off with it all the particles of carbon precipitated in the air. With the furnace however the ventilation might have been deranged by the explosion, and thus made worse instead of better at the very moment when most needed.

The CHAIRMAN remarked that another advantage in the fan, that had not been directly alluded to, would be the uniformity with which the ventilation was constantly maintained; he had no hesitation in saying that the loss of life from bad ventilation was much greater than that from explosions, as the men working in the pit were exposed to bad air constantly, and the effects must tell seriously on their health when the ventilation was defective for any length of time, which was liable to be the case frequently with the ordinary mode of ventilation.

Mr. RAMSBOTTOM thought the fan an exceedingly perfect machine; the leading feature in the mechanical arrangement appeared to be the enlargement of the fan to a size admitting of direct action of the small steam engine by which it was driven, the engine working at the same speed as the fan, thus dispensing with any intermediate gearing, and reducing the whole to the simplest form of machine, which could be readily kept in good working order. A second cylinder might easily be applied if desired at the other end of the same shaft, which would render any stoppage from the failure of the working parts next to impossible.

The CHAIRMAN proposed a vote of thanks to Mr. Rogers for his paper, which was passed.

Fig. 1. *General Section of Pit and Fan.*

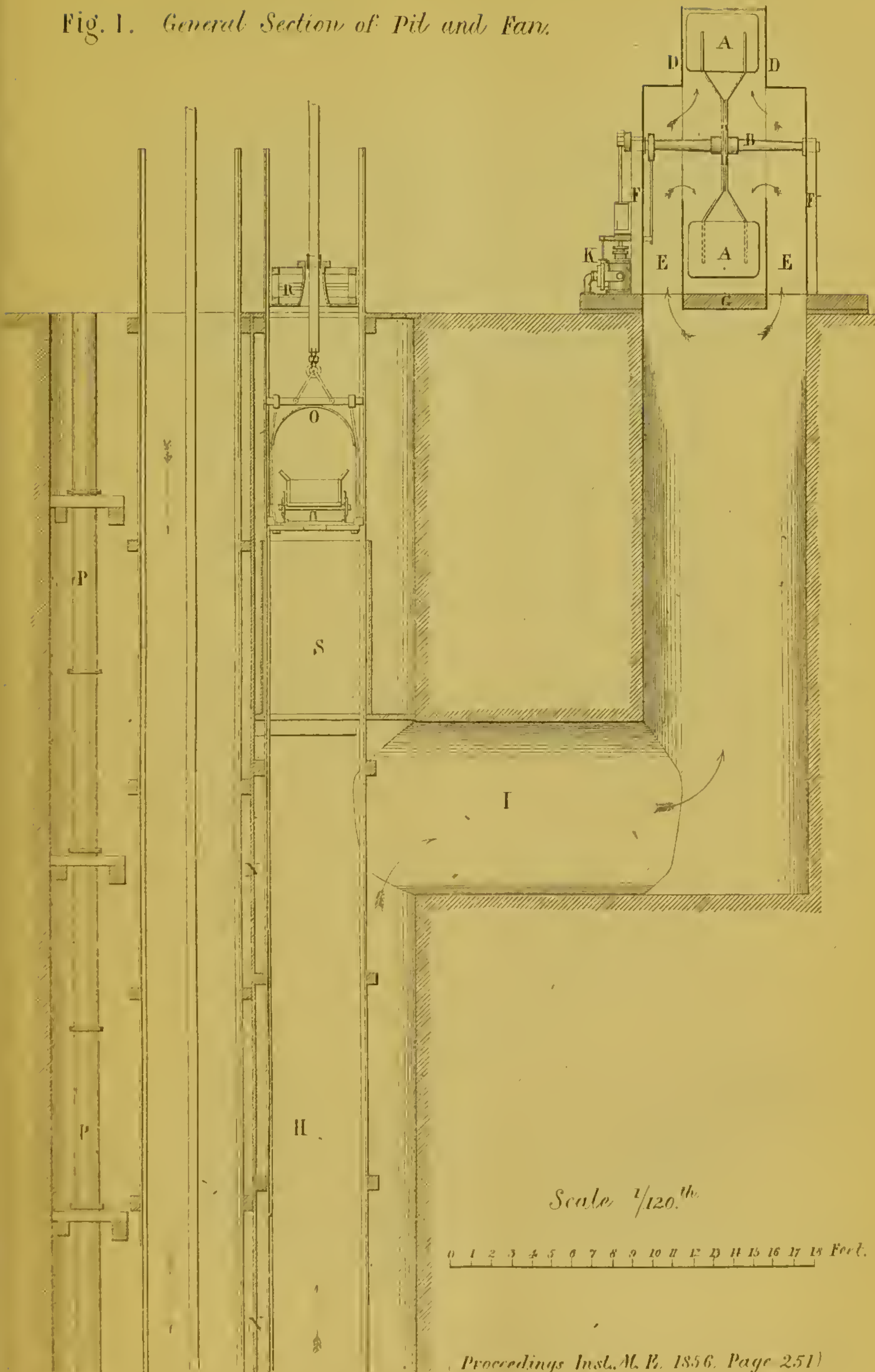


Fig. 2. Section of Pit showing Cage ascending.

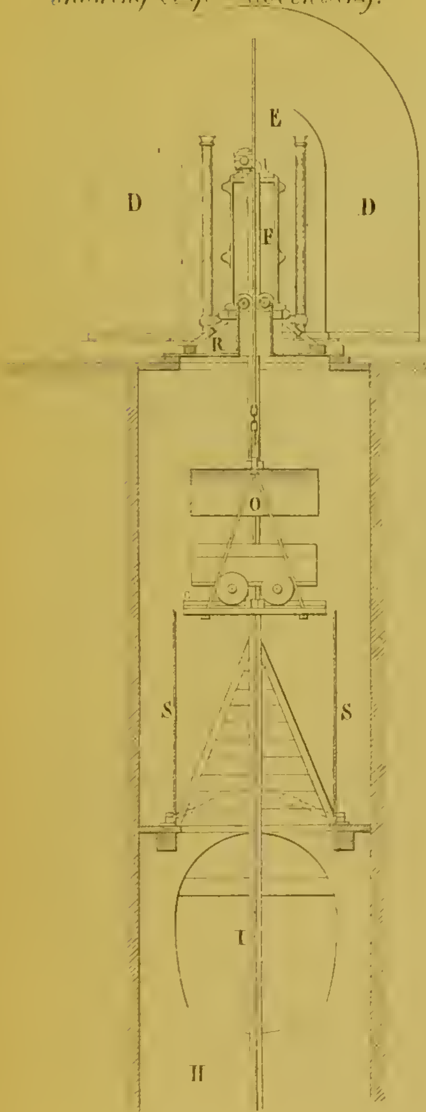



Fig. 3. Section of Pit showing Cage at top.

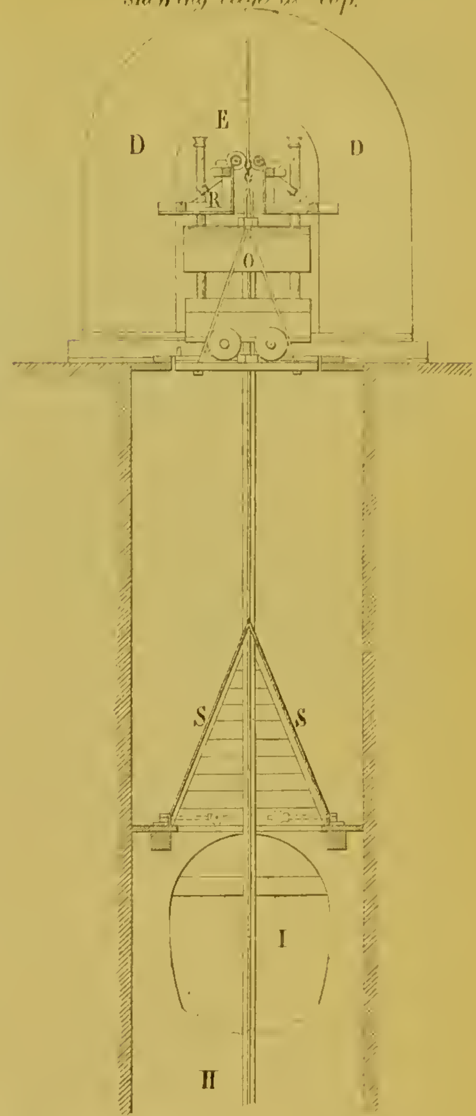
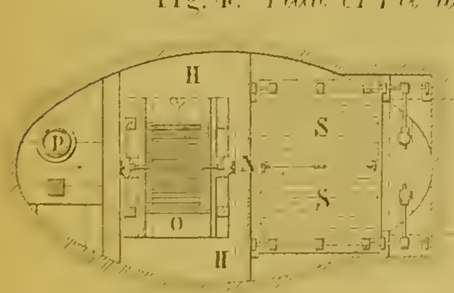
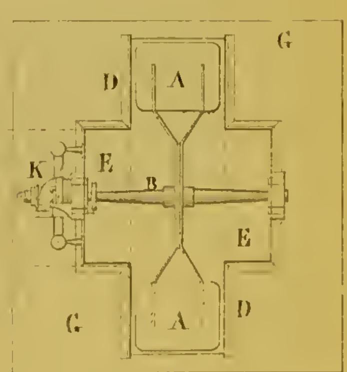



Fig. 4. Plan of Pit and Fan.




Scale 1/120th

0 1 2 3 4 5 6 7 8 9 10 11 12 24 36 Feet.

VENTILATING FAN.

Fig. 5. Side Elevation of Fan and Engine enlarged.

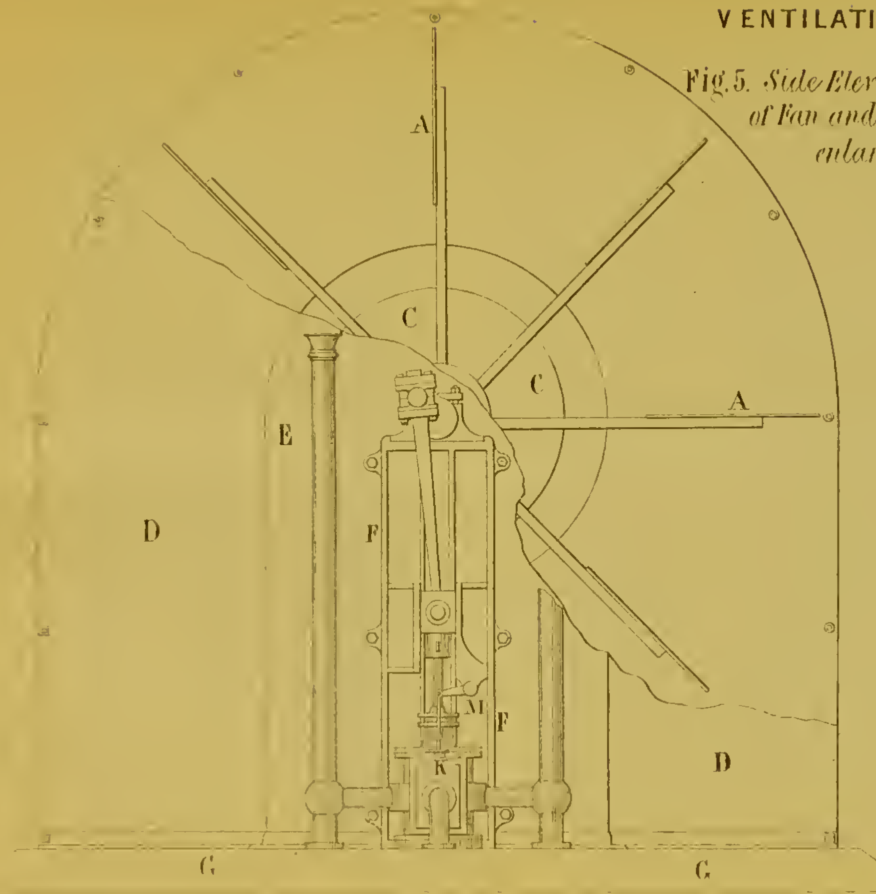
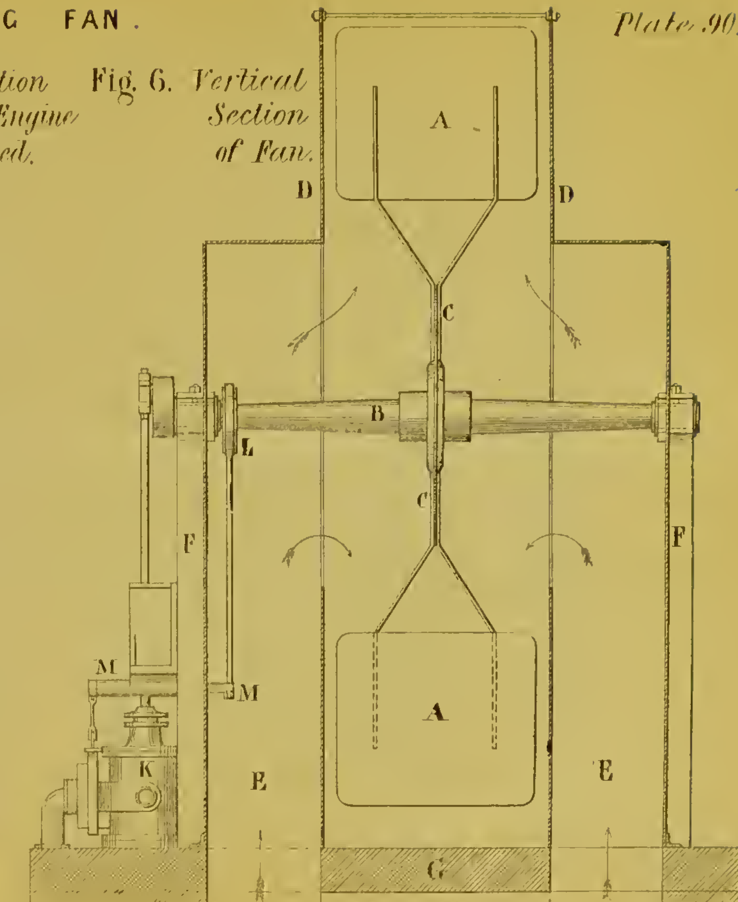



Fig. 6. Vertical Section of Fan.




(Proceedings Inst. M. E. 1856. Page 251) Scale 1/48th. Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

# DESCRIPTION OF THE VENTILATING FAN AT THE ABERCARN COLLIERIES.

The mode of ventilation that is still generally used in the collieries of this country is the old furnace ventilation, where the required current of air through the mine is maintained by the rarefaction of the column of air in the ascending shaft, by means of a large fire kept constantly burning at the bottom of the shaft. In Belgium and France, on the contrary, this plan is almost superseded by the use of machinery to maintain the current of air; as the furnace ventilation, although possessing the important advantages of great simplicity and freedom from liability to derangement from disturbing causes, has some serious objections and deficiencies, and in some cases becomes so imperfect a provision for ventilation as to render a better system highly desirable and even necessary.

The author of the present paper, having occasion to ventilate the workings in some extensive and very fiery coal seams recently won at Abercarn in South Wales, under circumstances where the furnace ventilation could not be applied, after carefully collecting every accessible information as to the ventilating machines used in Great Britain and on the Continent, came to the conclusion that a plan of machine proposed for the purpose some years since by Mr. James Nasmyth would be the most suitable and effective. After consultation with Mr. Nasmyth, it was resolved to test the principle and plan by actual practice; and the ventilating fan described in the present paper was made at Patricroft by Mr. Nasmyth, and is erected and now working at the Abercarn Collieries.

The general arrangements of the top of the shaft and the ventilating fan are shown in Figs. 1 to 4, Plates 88 and 89; Figs. 1, 2, and 3 are vertical sections, showing the air valves at the mouth of the pit, and the passage connecting the fan with the pit; Fig. 4 is a sectional plan of the pit and fan.

Fig. 5, Plate 90, is a side elevation of the fan and engine, to a larger scale; and Fig. 6 a vertical section of the fan.

The fan AA, Fig. 6, is $13\frac{1}{2}$ feet diameter, with 8 vanes, each 3 feet 6 inches wide and 3 feet long. It is fixed on a horizontal shaft B, 8 feet

7 inches in length from centre to centre of the bearings, which are 9 inches long by $4\frac{1}{2}$ inches diameter. The vanes are of thin plate iron, and carried by forked wrought iron arms secured to a centre disc C fixed upon the shaft B. The fan works within a casing DD consisting of two fixed sides of thin wrought plate, entirely open round the circumference and connected together by stay rods; the sides are 3 inches clear from the edges of the vanes, and have a circular opening 6 feet diameter in the centre of each, from which rectangular wrought iron trunks EE are carried down for the entrance of the air, the bearings for the fan shaft B being fixed in the outer sides of these trunks, which are strengthened for the purpose by vertical cast iron standards F bolted to them and resting upon the bottom foundation stone G.

The two air trunks EE join together below the fan, as shown in Fig. 1, and communicate with the pit H by means of a horizontal tunnel I, which enters the pit at 21 feet depth from the top.

The fan is driven by a small direct-acting non-condensing engine K, which is fixed upon the face of one of the vertical cast iron standards F, and is connected to a crank on the end of the fan shaft B. The steam cylinder is 12 inches diameter and 12 inches stroke, and is worked by steam from the boilers of the winding engine of the pit, at a pressure of about 13 lbs. per square inch. The eccentric L for the slide valve is placed just inside the air trunk E, and works the valve through a short weigh shaft M with a lever on the outside.

The pit H, Fig. 4, is of an oval form, 10 feet by 18 feet, and divided near the centre by a timber brattice N, the one side forming the upcast shaft and the other the downcast. Both of these are used for winding, and the cages O, in which the trucks, &c., are brought up, work between guides fixed to the timbering of the pit. The pumps P are placed in the downcast shaft.

In order to allow of the upcast shaft being used for winding, the top is closed by an air valve R, which is formed by simply boarding up the underside of the ordinary guard upon the mouth of the shaft, leaving only the hole in the centre through which the chain works. This air valve R is carried up by the cage O on arriving at the top of the shaft, as in Fig. 3, and then drops down again flat upon the opening when the cage is again lowered, as in Fig. 2. During the time that the valve is lifted, its place is

occupied by the close bottom of the cage O, which nearly fills the rectangular opening left at the top of the shaft. By this simple means it is found practically that a complete provision is made for keeping the top of the upcast shaft closed, and maintaining a uniform current of air up the shaft; for the leakage of air downwards through the top whilst the cage is in the act of opening or closing the air valve, and through the small area that always remains open, is found to be quite immaterial, and the surplus ventilating power of the fan is amply sufficient to provide against it.

In the original construction a more perfect air valve was supposed to be requisite, and was provided by the inclined flaps SS, which are fixed just above the horizontal tunnel I. These are fitted closely together, leaving only a small opening in the centre for the chain to pass through, and were intended to be opened by the ascending cage coming in contact with them, closing again directly by means of balance weights before the air valve R at the top of the shaft was opened, so as to preserve a thorough closing of the top of the shaft. The flaps were to be opened again by a lever from the top to allow the cage to descend. However, it was found on trial that the valve R at the top was amply sufficient; and consequently, although the other valves S were also provided, they have never been put into use.

The total depth of the pit is nearly 300 yards, and at a depth of 120 yards a split of air is taken off, and coursed through workings from which coal and fire clay are got; the larger portion of the air descends to the bottom of the pit, and is there split into many courses, to work two separate seams of coal and a vein of ironstone. The total length of road laid with plates or rails in the workings is about 7 miles, and the working faces amount to nearly double that distance. The longest distance that is traversed by any single course or split of air in passing from the downcast to the upcast shaft is nearly 2 miles. The quantity of materials raised from the pit is about 500 tons daily.

The speed at which the ventilating fan is usually worked is about 60 revolutions per minute, giving a velocity at the circumference of the fan of 2545 feet per minute; 45000 cubic feet of air per minute are then drawn through the mine, nearly one third of which ventilates the upper workings, and the rest passes through the lower workings.

Table 1 (appended) gives the results of a series of experiments made with this ventilating fan under the direction of the author by Mr. R. S. Roper, showing that the quantity of air delivered at the velocities of 60 and 80 revolutions of the fan per minute is 45000 and 56000 cubic feet per minute, with a velocity of current of 782 and 1037 lineal feet per minute respectively, or about 9 and 12 miles per hour; and the degree of vacuum or exhaustion in the upcast shaft is ·5 and ·9 inch of water respectively.

In these experiments the mode adopted for ascertaining the velocity of the air currents was by calculation from the difference of pressure, as observed by means of a carefully constructed vacuum gauge, the result being checked by the anemometer and by the time of passage of the smoke of powder fired at fixed distances by means of wires from a voltaic battery at the top of the shaft.

The working velocity of the fan is readily and instantly regulated by means of a throttle valve in the steam pipe of the engine, which is under the control of the man in charge of the working of the pit, and is adjusted according to the requirements of the ventilation arising from changes in the atmospheric pressure and in the quantity of gas in the workings. It has been found that a velocity of about 50 to 60 revolutions per minute gives the best amount of ventilation, and that beyond 80 revolutions the current of air is too strong to allow of the lamps being kept alight in the workings.

This ventilating fan has been now in constant work for two years, night and day, without once stopping for repairs of any kind, and is in as good working order as when first started; there appears to be nothing to get out of order about the machine on account of the simplicity of its construction, and no reason to anticipate any failure. The engine is made very simple in construction, with large and durable wearing surfaces, and the steam cylinder is fitted with a solid metal piston to prevent any occasion for stopping to adjust the packing. The whole cost of the steam power for working the fan is so insignificant that a little leakage of steam is quite immaterial. The complete arrangement would be to have a second duplicate fan fixed complete, and ready to be set to work at any moment if the first was stopped, or to work in conjunction with it on any emergency requiring greatly increased ventilation; though from the experience of the present fan it has not appeared requisite to take any such precaution.

In case of putting up another fan for a similar purpose, the author would adopt one of still larger diameter, probably 21 feet diameter, and running at a slow speed, which he considers would be preferable and still more economical in power. The construction of the casing of the fan he would propose to make of a simpler and less expensive description, using only thin brick walls for the sides and the air trunks. The whole expense would then be very inconsiderable, even for a complete pair of the ventilating fans.

The ventilating fan has a very important advantage over the furnace ventilation, in the power it affords of suddenly increasing the current of air to a great extent in any emergency; whilst with the furnace any increase is very slow in action and limited in extent, and cannot be effected from the surface of the ground.

Another advantage is the coolness and freshness of the upcast shaft, which can be used for the passage of the men as freely as the downcast shaft, being free from the heat and smoke of the furnace ventilation.

There is also no risk of explosion from the access of gas to the furnace fire; and in the first opening of a fiery seam, as in the present case at Abercarn, a furnace could not have been safely lighted until after a long delay for drainage of the gas, owing to the sudden and extensive liberation of gas, and even then it would have been attended with considerable difficulty and danger; but with the help of the fan all delay and danger was avoided, and the workings commenced immediately on reaching the seam.

A bratticed shaft was the only plan practicable in the present case, on account of the great difficulty of sinking deep through the rock, which was of remarkable hardness; and in such cases the furnace ventilation is very objectionable on account of the constant leakage caused by the drying of the timber of the brattice from the effects of the heat of the fire, and the corroding action of the sulphurous vapours of the furnace smoke.

By employing the suction in place of the blowing action, and having a fan of large diameter, great exhausting power is obtained without requiring a high velocity of rotation; the circumference of the fan case being left open allows the air to be expelled all round with perfect freedom, and the central diaphragm plate on the fan spindle prevents the opposite currents of air entering at each side from impeding each other. The simple manner of driving, by an engine acting direct by a crank on the fan spindle, saves the

necessity for intermediate gearing ; and by having the fan on the surface of the ground exposed to sight, its action and rate can be seen at all times to be effective, whilst it is safe from the chance of any damage arising from an explosion, were one to occur.

In the pit at Abercarn the quantity of gas is so serious that safety lamps are now used exclusively throughout the workings, and not a single naked light is allowed, except at the two stations near the shaft where the safety lamps are lighted and locked up. Several very slight explosions have occurred, but not any at all serious in their consequences, except one, which may be mentioned as a useful example of the great practical value of a means of suddenly producing a greatly increased current of ventilation, in preventing loss of life from the result of explosion. In this instance, which occurred about October, 1855, one of the men took a naked candle into a stall in which fire damp had accumulated in the lower workings, at about 150 yards distance from the shaft. An explosion ensued, which was heard by the author, who was at the top of the shaft at the time; and he instantly turned the steam full on to the engine of the fan, which immediately increased the speed of the fan to nearly double its rate, and caused such a sudden increase in the velocity of the current of ventilation, that the after damp resulting from the explosion was carried past the men in the workings so quickly that they escaped all serious injury, so momentary was their exposure to its effects. But if the ordinary velocity of current only had been maintained, some of these men could not have escaped with their lives. The man who caused the explosion was severely burnt, but recovered from the injury.

Almost immediately after turning on the steam to the fan, a shower of black particles was thrown out of the fan, which would be the result of the explosion, being the fine particles of carbon, liberated as light flaky soot from the decomposition of the carburetted hydrogen by the explosion. This is commonly but incorrectly called "coal dust," and is always the result of an explosion; and in the author's opinion this is the cause of the fatal effect of the after damp, from the accumulation of the minute solid particles upon the lungs, and not the exposure to the carbonic acid and nitrogen resulting from the combustion of the gas and air. This opinion is confirmed by the result of examination of the lungs of men killed by mine explosions, which are found to be loaded with these black solid particles. It has been observed

frequently that men ean live for some time in the after damp following a mine explosion, if they take the preeaution to eover their mouths and nostrils completely with a handkerehief, so as to sift the air they breathe and prevent these floating partieles of carbon from entering the lungs; and this precaution is enjoined in the rules of several mines, to prevent breathing the "eoal dust" as it is termed. The author has known a ease, where a miner, named John Hall, now living at Aberearn, got through a distanee of half a mile filled with the after damp by taking this preeaution, and eseaped with safety to the shaft.

One of the most explosive mixtures of gases that can be produeed in a eoal mine is in the proportion of 5 volumes of carburetted hydrogen and 40 volumes of atmospherie air. When this mixture is exploded the results are 2 volumes of vapour of carbon, 3 volumes of carbonie acid gas, 10 volumes of vapour of water, and 32 volumes of nitrogen gas. After the explosion the earbon assumes the form of light flaky soot, which is very finely distributed throughout the air. Table II. illustrates the manner in whieh the writer believes that the deeomposition and combinations aeeompanying the explosion take plaee.

A similar ventilating fan to that above described has been sinee ereeted by Mr. Nasmyth at Skiar Spring Colliery, near Elseear, whieh is working with eomplete suceess; it is of rather larger size than the one at Aberearn, being 15 feet diameter and 4 feet 3 inches wide in the vanes, and is worked at 80 revolutions per minute by the steam from a pumping engine boiler at 15 lbs. per square ineh. The result is a thoroughly effieient ventilation of the workings, completely under control at the surfaee of the ground, and maintained at an expenditure of fuel extremely small as eompared with that required for the ordinary furnaee ventilation.

TABLE I.

*Synopsis of Experiments on Fan Ventilation.*

| | Height of Barometer. | | Temperature by Fahrenheit's Thermometer. | | | | Revolutions of Fan per minute. | Water Gauge. | Velocity of Air in feet per minute. | Cubic feet of Air per minute. | Steam Gauge on Fan. | Theoretical Consumption of Coal per hour. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | At the Surface. | At the Bottom. | Top of Downcast. | Bottom of Downcast. | Bottom of Upcast. | 10 yards from top of Upcast. | | | | | | |
| | ins. | ins. | degs. | degs. | degs. | degs. | revs. | ins. | ft. p. min. | c. ft. p. min. | lbs. | lbs. |
| Mean of twelve experiments Natural Ventilation | 29·61 | 30·60 | 41·10 | 51·73 | 55·56 | 48·00 | ... | ·15 | 446·0 | 24325 | ... | ... |
| Mean of four experiments Fan Ventilation | 29·85 | 30·85 | 38·10 | 50·10 | 53·93 | 47·30 | 60 | ·50 | 781·8 | 45187 | 13·0 | 17·4 |
| Mean of five experiments Fan Ventilation | 29·65 | 30·61 | 41·40 | 50·70 | 55·10 | 48·70 | 80 | ·90 | 1037·0 | 56555 | 19·3 | 23·2 |

expectations – Through this I
shall be able with much greater
ease to obtain some facilities for you
to arrange a Paper on the S. Wales Iron
Ore – I have seen my Iron Mines
in S. Wales to the Sanitary Board Co. – this
will give you more data are here thus lately
– I do not know if you have seen
– the paper I send with this on the "Manu-
-facture of Charcoal & Coke" – it is an in-
-teresting subject – it has been little inves-
-tigated hitherto – I am following it
up now, by trying to ascertain the cause
of different Coals varying so much in their
value or power for Smelting Purposes –
& hope we are on the right track – The
Mechanical Structure of the Coke as you
see explained in the Paper herewith (Page 33)
has no doubt some influence; but the con-
-stituents of the Ash are no doubt of
great importance, — So far as the anal-
-ysis of Ash yet made are to be taken as
evidence – the "Potash" in the Coal seems

an element of ~~[illegible]~~ – I fear I
am too idle to follow up the working de-
tails of these analyses, but fortunately I
have a really able & true Worker, in my
assistant or Coadjutor here Mr. Ratcliffe
~~[illegible]~~
& now devoting his whole time to the an-
alysis of the Ash of the most Celebrated
Iron Smelting Coals – & to some also
notoriously bad, to work, although good
in appearance; we take the Specimens
not as they have been hitherto done, by
leaving the owners to pick out the best bits
but taking an entire Section of the Coal
in the Pit thus this gives the true
average of the whole; & quite a different
result from those picked – it is tedious
& expensive work; but in time I have
little doubt we shall collect enough
facts to generalize upon – at all
events there will be good work done
for Science and so to [illegible] –

Abercarn.
near
Newport. Mon. 23rd Oct 1857

My Dear Mr Percy

Your letter to my brother through Messrs Vardans – is enclosed to you here; my brother has left for Australia; & I thought he had seen you in London, & sorry he did not communicate with you – if I can be of service in preventing any disappointment from the paper on the Welsh Iron not being completed, I shall be happy to aid you – the subject is very important, & a really able account would be of National value –

I send you with this a number of the "Morning Advertiser" – in a leading article of which you will see some account of our "Institute of Engineers in South Wales" – we are now forming, & I have devoted some time to this lately & so far successfully [illegible]

Should hope of seeing you here this Summer – but suppose you have forgotten us – If you can run down here for a few days we shall be very glad to see you – the scenery here is still beautiful – We can find you a fair show of Iron & other ground to induce you to some fine mountain rambles – but better I trust than all you will have a hearty welcome – Please remember me very kindly to Ramsay, Smyth, Beete &c – your Institution is now firmly established, but I look back on the first work & struggling at its birth, often with pleasure but some sadness, in missing such noble men as De la Beche & Forbes from the ranks now – With sincere regards & wishes to yourself & Mrs Percy in which my wife joins – Yours faithfully

E. Rogers

4

# MEMOIR

OF THE LATE

# DAVID BOSWELL REID,

M.D., F.R.S.E., &c.

By HUGO REID.

*Suum cuique decus posteritas rependit.*

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# PREFACE.

My object in this publication is to vindicate the memory of a meritorious man, who, like many greater inventors, did not, during his lifetime, get the credit he deserved for what he had done, nor derive from his labours the reward he might fairly have expected. Those who have known of Dr Reid's plans for the ventilation of large buildings only by hearing them decried, will be surprised to learn that they have been in action in all their details in St George's Hall, Liverpool, for the last ten years; that they were attended with perfect success in the temporary House of Commons for the fifteen years during which that building was occupied; and that, in their essential features, they are still in operation in the Houses of Parliament.

It has been thought, also, that some brief account of his career would be acceptable to a wide circle of friends and old pupils. Of this, nothing more than a sketch, or outline, has been attempted.

H. R.

Edinburgh, *November* 1863.

# MEMOIR.

DAVID BOSWELL REID was born in Edinburgh, in the year 1805, and, like most of the youth of the place in those days, received the principal part of his early education at the High School, then in the building at the foot of Infirmary Street now occupied as a surgical hospital. At that institution he picked up a little Latin and Greek in the class-room, and in the play-ground a little experience of the rubs of life, with practical lessons—sometimes rather rough ones—in the art of standing his ground in the world—these being the only instruction and training afforded by the High School of Edinburgh in the early part of this century. Professor Pillans mentions him as "among the head boys of the Rector's class." Subsequently, under the care of Mr Walter Nichol, a very able and successful teacher, whose benches were crowded with pupils, he applied himself to the study of Mathematics, and greatly distinguished himself, having, in Mr Nichol's words, "placed himself at the head of my classes."

His attention was first turned to chemistry at an early age, when he went to be assistant at the chemical works of Mr Joseph Astley, at Portobello. Mr Astley was a manufacturer of Epsom salts and sal-ammoniac, a well-informed

scientific chemist, and a man of great ingenuity, who effected improvements in almost every process he undertook. There, no doubt, Mr Reid first became practically conversant with fumes, draughts, and furnaces, which were afterwards to occupy so large a share of his attention. It is probable, also, that chemical science came a good deal under his notice in his early days, in consequence of his father's intimacy with that distinguished chemist, the late Dr John Murray of Edinburgh.

After leaving Mr Astley's, he applied himself to the study of medicine, attending the medical classes at the university, and entering at an early period on the practical duties of the profession as assistant to the medical officers of that very valuable institution, the Dispensary. While pursuing his medical studies, he joined the Royal Medical Society, a long-established and highly respectable association of medical students, for the purpose of improving themselves by writing and discussing papers on medical questions, and providing a reading-room and library. The most active, talented, and promising of the medical students were always to be found among the members of this Society, and four of the most popular and distinguished were elected yearly to be presidents. In the session 1826-7, Mr Reid was chosen senior or first president of the Society, succeeding in that office to James Phillips Kay, now better known as Sir James Kay Shuttleworth, who has done so much for the cause of education.

The following extracts are from a communication with which the writer has been favoured by Dr W. A. F. Browne, one of the Commissioners in Lunacy for Scotland, formerly one of Mr Reid's colleagues in the presidency of the Royal Medical Society :—

" My recollections of your brother, Dr D. B. Reid, are, even after a lapse of thirty years, very distinct and agreeable. This was partly the result of his prominence in the

University community, and partly because we were brought much and closely into contact. We were fellow presidents of the Royal Medical Society in 1826-7. At that time the Society was exceedingly prosperous, and contained the most distinguished and earnest students; and supplied means of training, and of testing knowledge, in which the University was deficient. Your brother took a very active part in its proceedings, and was a popular, and, upon his own subject, a powerful debater. While our respect towards him—and every one cherished such respect—was in some measure founded upon his unapproachable superiority in the much dreaded science of chemistry, the feeling was deepened by his great energy and industry, by the *abandon* of all minor objects, even of legitimate pleasures, for the pursuit of science."

"I came occasionally into contact with your brother, in the scene of his early triumphs in Roxburgh Place. I examined his experimental premises, became familiar with his views, and was impressed, not merely with the soundness of many of the principles upon which ventilation of large buildings could be effected, which he held, but felt convinced that my early friend was destined to become distinguished, and, above all, a practically useful man of science."

But he was not destined to pursue the medical profession. The rapid growth of the science of chemistry—perhaps unequalled in the history of science, unless by geology—with its numerous and daily increasing applications to the arts and manufactures, rendered it very desirable that some easy means should be afforded of acquiring practical skill in the art of experimenting. Though, no doubt, practical lessons were given by some lecturers to such pupils as desired them, and could afford to pay handsomely for them, there were no systematic practical courses, at a moderate rate, adapted to the many. Thus, hundreds, who would them-

selves have greatly benefited, as well as have conferred benefits on society by their researches, were deterred from the pursuit of chemistry experimentally, by the expense and difficulty of the first step, and the field of labourers in this new science, which had such intimate relations with almost every art and manufacture, and many branches of physical science, was greatly restricted. Towards the close of his medical studies, Mr Reid's attention was directed to this great want, and he conceived the idea of establishing systematic courses of practical lessons in chemistry, in which the pupils themselves should perform the experiments, going through all the steps of a process with their own hands, and thus at once having the facts and phenomena impressed on their minds, and acquiring a practical knowledge of chemical materials, and skill in chemical manipulation. The project, commenced under considerable difficulties, was attended with great success ; at first in a small and inconvenient room in the High School Yards, then in a room in the University, when Mr Reid became assistant to the Professor of Chemistry, and afterwards in a class-room of his own, behind the present Hall of the College of Surgeons. He continued these practical classes for upwards of thirteen years, till he removed to London in 1840. They became extremely useful and popular, and were attended by hundreds of all ages and classes,—medical students, miners, manufacturers, engineers, agriculturists, amateurs. Side by side with the youth just entering his studies, might be seen the veteran, who perhaps had served his sovereign in the four quarters of the globe, or an elderly amateur of a philosophical turn, glad to avail himself now of what, perhaps, he had longed for, but could not obtain, in his youth,—all delighted to be putting their own hands to work with the retort or the crucible, to see the metamorphoses brought about by their own efforts, to acquire practical skill in chemical operations, and to have the theory fixed in their

minds along with the practice, by the clear demonstrations given from time to time by Mr Reid. Referring to these classes, the late Dr George Wilson remarks, in his Life of Edward Forbes :—" Shortly before Edward Forbes began his medical studies, Dr David B. Reid, beyond the University walls, had commenced a system of instruction in practical chemistry, which, for the time, was a great advance. It aimed more at enabling each student to familiarize himself by experiments made under the directions of a teacher, with the properties of the chief chemical substances, and the phenomena attending their action on each other, than at making him a practical chemist in the sense of an analyst; but it did something for him also in this respect. The introducer of this system was a man of great energy, and by satisfying, to some degree, a strongly felt want of the time, laid the foundation of our educational system of practical chemistry." These practical classes were not meant to supersede the more minute analytical course, in which each pupil carried on a more careful and independent series of experiments adapted to his special object. But the practical class, organised to carry on numbers together, on moderate terms, initiated all in the rudiments of manipulation and leading facts of chemical science, and formed able practical chemists of many who required only the first start in experimenting to be able to go on for themselves.

Not long after starting his practical courses in the High School Yards, Mr Reid became assistant to Dr Hope, Professor of Chemistry in the University, by which he had the advantage of a room in the College in which to carry on his classes, and of an introduction to the very large class which then attended the course of that able lecturer. In the year 1829 the Royal College of Surgeons of Edinburgh introduced practical chemistry into the curriculum for their diploma, a step, there is reason to believe, greatly promoted by the marked success of Mr Reid's practical classes. This,

however, placed Mr Reid in a dilemma. To qualify a student for obtaining the diploma, it was not enough that he had the requisite knowledge and practical skill; these must have been acquired at the class of some privileged teacher—Professor of an University, or Fellow of the College of Physicians or of Surgeons. Mr Reid was, so to speak, an unprivileged teacher. The College of Surgeons, however, with great liberality, considering, as stated in their Report, "the very peculiar circumstances in which Mr Reid, who has been for sometime past a most industrious and successful teacher of practical chemistry, would be placed in consequence of the late regulations of the Royal College, were his courses not held to qualify his students for examination," paid him the high compliment of extending to him a special license, by which his ticket should qualify for their examination for two years, thus allowing him time to qualify as a lecturer in the usual way. This he did by taking the degree of M.D., and entering the Royal College of Physicians of Edinburgh, one of the learned corporations which have the privilege of dispensing such knowledge as medical students require.

In 1833, urged on by some sanguine friends and admirers, Dr Reid was induced to lay before the patrons of the University (the Town-Council of Edinburgh) a proposal to institute in the University an independent Professorship of Practical Chemistry. Many plausible reasons were advanced in favour of this scheme, but it was strenuously opposed by Dr Hope, and the Senatus Academicus reported against it. The class was looked upon as naturally connected with the old established chair of Chemistry, though the Professor had hitherto only delivered lectures, never having taken any part in the practical courses. It was considered that, though Dr Hope, at his advanced period of life, could not be expected to undertake it, one Professor might fulfil the duties of both classes, and that it was not desirable to

diminish (for his successors) the value of the Chemical Chair, by creating a new one. The question was remitted to the College Committee of the Council, who reported, "although only by the casting vote of the Chairman, that, "under all the circumstances, it is not expedient to do "so, at least at present." When the Council came to a vote on the subject, it appeared that they also were equally divided, fourteen being in favour of the proposal, and the same number against it. The matter was decided by the Lord Provost (Mr Learmonth) giving his casting vote against the creation of a separate Chair of Practical Chemistry. Considering the great local influence of Dr Hope and his friends, as well as of the Senatus Academicus, and the questionable expediency of the project, the vote of the Council must be taken as a strong mark of the popularity of Dr Reid and of the esteem in which he was held by his fellow-citizens. Some, doubtless, would point to it also as a proof of the unfitness of the Council for a charge, of which Parliament has now relieved them. It was perhaps fortunate for Dr Reid that the proposal was not acceded to. Had the chair been created, he would, there is little doubt, have been appointed Professor. It is by no means clear that Practical Chemistry, alone, would have been sufficiently remunerative; and it is highly probable that Dr Hope would have carried the question into the courts of law, and tested there the claim of the Council thus to encroach upon what he regarded as his rights.

Dr Reid left the College in 1833, and established himself as a private lecturer on chemistry, in a class-room which he built behind the present Surgeons' Hall. His lectures and practical classes were crowded, and he was regarded as one of the ablest, as he was one of the most popular and successful lecturers in Edinburgh. His lectures were remarkable for their style of "lucid exposition," as Dr Chalmers expressed it, and for the brilliancy and invariable

success of his experimental illustrations. He was seldom if ever placed in the awkward position of failing in an experiment—of telling his class that such a change would take place, while the inert materials defied him, and refused to exhibit the predicted phenomenon. He owed this success to his thorough knowledge of all that could affect the operation, and the extreme care he ever took in making the necessary previous preparations—qualities that, with his undoubted inventive faculty and fertility of resources, would most probably have led him to distinction as a chemist, had he not been drawn aside to other pursuits. At the close of one of his popular courses, which was attended by Sir John Leslie, Rev. Dr Chalmers, General Sir Joseph Stratton, Professors G. J. Bell and Pillans, Rev. E. B. Ramsay, Rev. J. Williams, George Combe, Esq., and many others of the principal citizens, his class, highly pleased with the course, and sensible that he had spared neither trouble nor expense—in fact, made very great exertions—to render it attractive and interesting, presented to him a piece of plate in token of their approbation and gratification. He was ever ready to aid in any movement for the public good. He originated and took an active part in promoting and conducting an exhibition of Arts and Manufactures, in 1840. His departure from his native city to settle in London was much regretted by his townsmen, who presented to him a handsome piece of plate as a token of their esteem, and gave him a farewell entertainment, at which Sir J. Graham Dalyell presided.

In 1835, when a new building for the Houses of Parliament was in contemplation, a Committee of the House of Commons was appointed to consider the subjects of warming, ventilating, and acoustics, with reference to the new building. The uncomfortable and positively injurious state of the air in the halls of the Legislature had long been complained of, and was found still more oppressive in recent

times in consequence of the long sittings which had become so frequent, the impure state of the river, factories, and a crowded population in the vicinity. In the old buildings, burned down in 1834, the Members, besides suffering from the bad state of the air, had been much incommoded by the difficulty of hearing well in many parts of the house. With respect to the air, one Member said, "Many of our eminent public men are exposed for many hours to a deleterious atmosphere in the House of Commons," and Lord Sudeley (formerly Mr Hanbury Tracey), who had been chairman of the Commissioners for selecting the design for the new Houses of Parliament, wrote in 1843, referring to the old House, "The pestilential atmosphere of the House of Commons was notorious; its baneful effects on the health and energies of its Members were painfully felt and admitted: means from time to time were resorted to, to correct the evil, till scarcely a hope, if any, remained even that it could be lessened, and the most sanguine never dreamt that it could be cured;"—and, again, "Much money had been fruitlessly expended, and the skill and science of the most learned chemists had been enlisted without any beneficial results."—No sooner had something been learned of the laws of pneumatics, towards the close of the seventeenth century, than the oppressed legislators, thinking that the philosophers knew, or ought to know, something of the matter, applied to them for relief. In the year 1700, Sir Christopher Wren, an architect, as well as a philosopher, was consulted, but was unable to effect any material improvement. A little later, Desaguliers, the eminent natural philosopher and engineer, was applied to, but with no better result. The subject was particularly considered by a Committee in 1791, and some alterations were made, but with little benefit. In 1810, Sir Humphry Davy was equally unsuccessful in endeavouring to improve the state of the air in the House of Commons. The problem was

evidently a troublesome one, from the peculiar circumstances attending the sittings of the House—some Members remaining in it often from six to eight hours or more, while the attendance was most unequal and changeable, varying from fifty to upwards of eight hundred in the course of one sitting.

In the construction of his class-room, Dr Reid had paid special attention to ventilation, and introduced very efficient arrangements for carrying off the fumes and noxious gases evolved during the numerous experiments performed daily in his lectures and practical classes. In its form, the room was admirably adapted for hearing. These circumstances having become known, Dr Reid was summoned to give his evidence before the Parliamentary Committee on acoustics and ventilation. The Committee included many leading Members of the House, as Mr B. Hawes (chairman), Mr Hanbury Tracey (Lord Sudeley), Lord Howick (now Earl Grey), Lord Granville Somerset, Lord Sandon (now Earl of Harrowby), Sir George Clerk and Mr Warburton. The witnesses examined were, Dr Birbeck, Dr Faraday, Mr Brande, Mr Sylvester, Sir Robert Smirke, and Dr Reid. On reading the evidence laid before this committee, including the questions put by the members, it is impossible to avoid being struck by three things,—*first*, the strong sense entertained by the Members of the very defective state of the House of Commons as to both ventilation and hearing; *next*, the intelligence and acuteness of the Members of the Committee, as evinced by their questions and remarks; *third*, the clear, decided and satisfactory nature of the views developed by Dr Reid. The Committee saw at once that he spoke as a man thoroughly conversant with the subject, fully alive to their wants and the evils from which they suffered, and provided with an efficient and adequate remedy. When Dr Reid proposed to apply a power to draw or force air through the House, a power which should place

the state of the air under perfect control, capable of regulation according to circumstances—and to admit the air by numerous apertures in the floor, so that while a draught should be ensured every where, it should not be felt any where—they saw that he had taken the bull by the horns, and, approving also of his plans for improving the state of the hearing in the house, the Committee resolved on a report, in which they specially directed attention to his evidence, and recommended that his plans should have a trial in the temporary House of Commons. The alterations he had proposed were made during the autumn of 1836, and were attended with complete success—a success which continued during the fifteen years which elapsed before the new Houses were occupied, and was testified to again and again, cheerfully and gratefully, by both leading Members individually, and Committees of the House. This is a well established point; but, considering what has passed, it is desirable to produce some of the evidence on which it rests.

There could be no higher authority on the subject than Lord Sudeley, the chairman of the Commissioners for selecting the design for the new Houses, who was intimately conversant with the whole progress of the question as to the ventilation of the Houses. In a letter to Dr Reid, in 1843, he states that the ventilation had been brought "to such a degree of perfection as to defy the chills of winter and the heat of summer, or the effects of numbers, however great, congregated within its walls, lessening its beneficial effects. To your skill, zeal, and determination it is owing that the Members of the House of Commons can now pursue their senatorial duties without sacrifice of either health or comfort—to you we owe the solution of the problem, that, by a proper system, ventilation may be obtained in the most trying and difficult situations." And again, in his place in the House of Lords, in 1846, Lord Sudeley "asserted that the ventilation of the House of Commons

was most complete and perfect, and was the first plan of systematic ventilation ever carried out in this or any other country." Mr Hawes, chairman of the original Committee on Ventilation, says, in a letter to Dr Reid, " You have facilitated public business and prolonged the lives of public men." A Committee of the House of Commons, in 1846, after Dr Reid's plan had been ten years in operation, reported—" The great improvement which Dr Reid has effected in the atmosphere of the existing House of Commons can be appreciated by every Member of the House, and your Committee entirely concur in what they consider to be the general opinion in its favour ;" and in the same session another Committee, of which Sir Robert H. Inglis was chairman, adverting to the difficulties between Mr Barry and Dr Reid, distinctly recommended a plan of adjustment with the view of carrying out Dr Reid's plans in the new Houses. The strongest testimonies might also be produced from the Speaker (Mr Lefevre), Lord Campbell Lord Monteagle, Earl Grey, &c. Mr Horace Mann, the distinguished American educationist, in his " Report of an Educational Tour," states, " The only public edifice I saw in Europe which enjoys a perfect luxury of ventilation was the British House of Parliament. The plan is scientific and the apparatus for executing it complete ;" and abundance of other testimonies from foreigners might be adduced.

One difficulty which Dr Reid experienced at the commencement of the working of his plans in the House arose from the different tastes and requirements of the members as to air and warmth. One desired a low temperature, another a high one ; some members preferred the air moist, while others required a dry atmosphere ; some were indifferent as to impurities, to which others were very sensitive. These varieties of feeling were caused partly by inherent constitutional differences ; partly by differences as to condition at the time, such as might arise from more or

less clothing, from being heated by exercise, or the reverse, and very much depended on the state of that great regulator, the stomach. Perhaps one member

> . . . was not taken well,
> He had not dined;

another had not only dined, but dined well, and had a generous allowance of wine. Dr Reid states in his "Illustrations of Ventilation," that when the House first met after the new ventilating arrangements were in action, one member said to him, "The temperature is rising; we shall be suffocated immediately;" while another declared he was shivering from cold. Some, he states, demanded a temperature of 52°, while others were hardly satisfied with a lower temperature than 70°. These opposing feelings were humorously described by "Punch" in a clever parody of Allan Cunningham's spirited song, "A wet sheet and a flowing sea," beginning, "With wet feet on a Committee," and in which occurred the lines, after describing the opposite demands made,—

> ". . . So Dr Reid made free
> To give it to us half-and-half,
> And wretched men were we."

This difficulty, however, did not long continue to give trouble. It was soon seen that every one could not get the atmosphere peculiarly suited to him, and that some average, to be varied a little according to circumstances, must be agreed on; and the beauty of the system was that any state of the air which might be desired was at command. But Dr Reid did not exactly "make free" to give what he pleased. He was in constant communication with the Speaker and the Sergeant-at-arms, and, by consultation with them and the members, was enabled to provide an atmosphere suited to the wants of the great majority. In the work quoted above, Dr Reid says,—"The House is

heated to 62° before it is opened, and maintained in general at a temperature between 63° and 70°, according to the velocity with which the air is permitted to pass through the House. This velocity is necessarily regulated by the numbers present on a given space, the temperature to which the air can be reduced in warm weather, and the amount of moisture which it may contain when the quantity is excessive. Some members are much more affected by an excess or deficiency of moisture than by alterations of temperature." "In extremely warm weather, by increasing the velocity, air even at 75° may be rendered cool and pleasant to the feelings."

"The temperature may always be advantageously increased, and the velocity diminished, before the usual dinner hour. After dinner, other circumstances being the same, the temperature should be diminished, the velocity increased, and the amount of moisture in the air reduced, when practicable. During late debates, as they advance to two, three, four, or five in the morning, the temperature should be gradually increased as the constitution becomes more exhausted, except in cases where the excitement is extreme."

"Those who have been recently riding, dining, or engaging in any exercise, and whose circulation is accelerated, feel a medium atmosphere too warm. On the other hand, after a cold drive in a carriage, the temperature cannot be raised too high till the constitution shall have been warmed, as it were, to an average standard. In an extreme case, during the severe winter of 1840–41, several members having entered the House of Peers after being very much chilled, incessant demands were made for more and more warmth, and the temperature was at last brought to 74°. But even this was insufficient; and I accordingly suspended the ventilation entirely, and kept the air as quiescent as possible, till the effects of the excessive external cold had passed away."

Such were the varied considerations which had to be taken into account in regulating the ventilation, and by studying which, the temporary House, occupied for fifteen years, became a "luxury of ventilation," as Horace Mann expresses it; a luxury, however, or rather necessary, which members who spent from six to ten hours in the House daily for six months required, and to which they were well entitled.

At first, the cost of the new ventilating arrangements was complained of by some. Perhaps this might have been expected. People had hitherto been accustomed only to the chance action of what has been called "natural ventilation;" and not appreciating sufficiently the importance of pure air, nor the very special circumstances in which the Houses of the Legislature were placed, doubted the necessity of a system, certainly costly when contrasted with that which formerly prevailed. Retrenchment was the order of the day; and it was not unnatural to wonder at the amount now to be laid out on what had previously cost nothing. But no members who had had experience of the wretched state of the old Houses as to ventilation grudged the cost of an efficient plan for removing the evils under which they had suffered. The unreasonableness of expecting a good system of ventilation on the same easy terms as the previous methods, which had been so total a failure, soon passed away; while it came also to be seen that, for certain public buildings, thorough ventilation was an absolute necessity. As knowledge and civilisation advance, new wants are felt, such, for example, as the improvement and extension of education; but they cannot be supplied for nothing.

From the expense of the ventilation of the Houses of Parliament and St George's Hall, injustice was sometimes done to Dr Reid from the hasty inference that he could do nothing in ventilation without complex and costly methods such as had been there introduced. But he was daily im-

proving the ventilation of numbers of buildings where much simpler plans sufficed, or where, though he might advise the most efficient system, the proprietors were content with cheaper modes.

The success of the new ventilating arrangements, introduced by Dr Reid in the House of Commons having been so marked, and the benefit to the members so strongly felt and appreciated, especially by the older members who had suffered so much under the former system (or rather no-system), the Government desired that his plans should be introduced in the new Houses. Accordingly, in 1840, an arrangement was come to by which Dr Reid was to settle in London and devote part of his time to superintending the ventilation in the temporary House, and making arrangements for the ventilation of the new building. Some of his friends doubted whether, on this occasion, he exhibited sufficiently the faculty generally attributed to his countrymen, of making a good bargain for themselves, and did not wish him to leave Edinburgh, where he was much esteemed, and occupied the highest professional position with the fairest prospects for the future. But Dr Reid had publicly staked his reputation upon his ventilation schemes, and naturally seized the opportunity offered him of carrying them into operation in the foremost edifice in the kingdom, while he looked, and reasonably, to an extensive business in private consultations; a prospect fully realised till the press commenced to run him down.

But there was one unfortunate feature in the new arrangement, which led to innumerable difficulties, in both the ordinary and American sense of that word, and ultimately to the loss of his services at the Houses of Parliament. Dr Reid had not uncontrolled power to carry out whatever he judged necessary for his purpose, as he had with the temporary House. He was to consult with the architect, Mr Barry, and any differences between them were

to be referred to the Board of Works. The distinguished architect, whose genius, fine taste, and antiquarian lore, have created so noble an edifice, so truly classic, in a British application of that term, must have felt himself in a new and strange position. He was not, as in other cases, master of his own work. Another party had a right to say, There must be an inlet for air here of such a size, there an outlet, here a passage, and so on. He had been accustomed to be lord of all he surveyed, but was now to be hampered by one whom he probably viewed as an intruder into his proper domain. This could not be pleasant, but it was unavoidable; it was the penalty which architects had to pay for having ignored ventilation. As Dr Birbeck said in his evidence,—"Heat and ventilation, especially the latter, seldom enter into the mind of the builder when he projects his building,—he begins as if he did not know that ventilation could be necessary." There can be no doubt that the architect and ventilator should be one and the same person; but the Members of the House of Commons had suffered too much from bad ventilation; it was matter of notoriety that architects at that time knew little or nothing about it; and therefore another party, who had proved his knowledge and skill in the matter, had to be conjoined with the architect in the transition state of the ventilation question at the time when the new Houses of Parliament were planned. So Reid and Barry found themselves thrust into frequent communication with each other in circumstances which ultimately became fruitful in difficulties and conflicts. For a time, things went on smoothly, but about 1845, if not earlier, disputes and difficulties became more frequent and more acrimonious: ere long, the architect and the ventilator were not on speaking terms, and business between them was transacted through the medium of third parties or tedious written statements involving a fearful amount of trouble as to

matters that would have been settled in a few minutes by a few words in a friendly spirit. The Board of Works had frequently to be appealed to, and in 1846 a lengthened reference and investigation took place before Mr Gwilt, an architect, which, as in so many other cases, had no other result than a huge blue book. Some time later, the climax was reached, when Mr Barry prosecuted Dr Reid for a libel. Dr Reid had used some strong expression in characterising a paper drawn up (or sanctioned) by Mr Barry, purporting to be the minutes of a conference held. Mr Barry called on him to retract the expression or statement complained of. Dr Reid refused. Mr Barry then instituted an action at law against him. But it was ruled that the paper with the statement objected to was a "privileged communication," and the case was decided in favour of Dr Reid, who, while thus gaining his cause, suffered at the same time, as often happens, a considerable pecuniary loss.*

Any account of the career of Dr Reid would be imperfect that did not notice a circumstance which brought him into undesirable notoriety—the attacks of the Press. About this time (1845–47), he must have had some very zealous enemies. From the unwonted nature, pertinacity, and singular virulence of these attacks, as well as from circumstances which have come to his knowledge, the writer believes that, for the most part, they were instigated by persons who had strongly interested motives for depreciating Dr Reid and his plans for ventilation. On mere public

* It is not the desire of the writer to give any opinion as to whether the one or the other of these eminent men was to blame for the unfortunate difficulties that arose between them. Both have now passed from this troubled scene—"de mortuis nil nisi bonum." But, without meaning to infer therefrom that Dr Reid was in the right in this particular instance, it is due to his memory to state that he was well known as a man of a most kindly nature, affable, good natured, and obliging in his disposition and manners. That this was his general character, hundreds could testify.

grounds—such as a public journal could properly take up—they were utterly inexplicable.

When his plans had been in successful action in the House of Commons for eight years or more, and his employers and those directly affected by their operation—those who alone had access to an intimate knowledge of his works—the Government, the Board of Works, and the Members of the House of Commons—were expressing their entire satisfaction with the results, the leading daily journal began to denounce him and his system, and for a time, continued to endeavour to run him down, in a series of articles, perhaps unprecedented in the history of the Press. A few specimens are necessary to convey some idea of the statements of his assailant:—" A more egregious failure than Dr Reid's ' experiments' have hitherto proved, cannot be imagined. We have not heard of one individual to whom they have been ' extremely advantageous' except it be Dr Reid himself." " That which has hitherto proved so monstrous a failure." " The utter inefficiency of Dr Reid's system of ventilation." " The present abominable system." " He obtains a percentage on the cost of the experiments which he is hourly trying on what he may deem so vile a body as the present House of Commons." In this style, the subject was recurred to again and again, often in leading articles. Here was evinced an extraordinary determination to do all in its power to injure a man's professional reputation by a public journal; the writers in which had no occasion at all to refer to the subject, who could not meddle with it without going very much out of their way, and who were neither in a position to know, nor competent to judge of what he had done. In truth, such was their zeal in running him down, that they sometimes blamed him, and made a long tirade against him, for matters he had had nothing at all to do with.*

* The utter indifference to *facts*, sometimes exhibited by gentlemen of the

In the year 1845, Dr Reid judged it necessary to publish a reply to *The Times*. Though its attacks had not the slightest effect on the Board, the Government, or the Members of the House of Commons, who knew well how unfounded they were, they operated most injuriously against his private business, the prospect of which had been one of his main inducements to remove to London. But his reply, though most convincing to those who read it, could have little force against the denunciations of so powerful a journal, which took no notice of his defence. A journalist never cries *peccavi;* he is infallible—another Pope in fact; and, as Mr Pendennis says, "has omniscience at his pen's end, and is ready to lay down the law on any given subject—to teach any man his business." There is no doubt that these repeated attacks were successful in wounding the feelings of a faithful and laborious public servant, who had performed his duties to the entire satisfaction of his employers and of all who were in a position to be able to judge, damaged his professional reputation, and lessened greatly his professional income from private consultations. For such injuries there was no redress.

It seems proper here to quote a few lines of Dr Reid's remarks on the subject:—

"The writers in that paper, without the general or special knowledge essential for forming a judgment on the question, without inquiring whether the matter complained of was the result of my *system* or not,—without knowing whether or not I was in any degree responsible for the *management* in the particular instance referred to,—have blamed and

Press, in statements calculated to injure, is surprising. One journal asserted that Dr Reid's ventilation of the steamships of the Niger Expedition was "a total and a signal failure." For effective ventilation, this was one of his most successful works, as amply testified, on several occasions, by leading officers of the Expedition. There still seems a want of some "Code of Honour"—some established rules of courtesy, fairness, and caution, proper to be observed by writers of the Press in remarks affecting character and professional reputation.

abused me for every instance of dissatisfaction with the state of the atmosphere in the Houses of Parliament and their committee rooms; have seized every occasion to attack what I have done in other places which I have been engaged to ventilate; have again and again recurred to the subject with a pertinacity, and in a spirit showing a determination to do all in their power to injure me.

"There has always appeared to me something not directly accounted for in the conduct of the writers in *The Times* towards me. Their repeated recurrence to the subject, the pains they have taken to go out of their way to disparage my plans, their not scrupling, as I have shown, to suppress, invent, and misrepresent, either for the sake of doing me an injury, or at least proceeding with a recklessness equivalent to the same; the virulence, coarseness, and pointed personality of their style, on a subject which is eminently free from the usual sources of excitement and angry feeling,—all conspire to show a design to use their power to injure my reputation, both private and professional, or that they are the tools of others in attempting to effect this object."

Strange to say, too, the great literary periodical of the day, the "Quarterly Review," did not scruple to stoop to lend its pages to an endeavour to run him down. An article appeared there on Ventilation, the sole purport of which was to throw ridicule on his plans and his descriptions of them. It did not contain a single line of useful information, or serious discussion, but was, throughout, a tissue of those cheap commodities, ridicule and sneer; and very dull and commonplace it was. Its hardest hit was asserting that "the subject and object of Dr Reid's experiments may be reduced to the common formula of £ s. d.," which was thought so good, that the £ s. d. was brought in several times. The best joke was, suggesting that a committee, with Mr Benjamin Hawes as chairman, should inquire into

the ventilation of Noah's Ark! The article proved nothing but that some one felt very spiteful towards Dr Reid, and that the accomplished editor had been incautious in admitting a paper so unworthy in its object, and so inferior in tone and style, that he must have been heartily ashamed of it when he saw it in print.

That the freedom of the press is not an unmixed good, we have abundant proofs daily. As a people, it has brought and secured to us inestimable advantages; to individuals, on the other hand, it has often been productive of outrage and injustice. But it is seldom that this great privilege has been so grossly abused as by the writers who, leaving their proper path, and far overstepping the bounds of courtesy, common fairness, and truth, dragged into public view the subject of this memoir, and endeavoured to bring him into public odium, in a series of calumnies to which not one of them would have dared to append his name.

In 1846, the House of Lords, desirous of entering immediately into the chamber prepared for them in the new building, and believing that this would be greatly delayed by the difficulties between Dr Reid and Mr Barry, adopted a course which resulted in transferring the ventilation of their new House and other parts of the building, to the hands of the latter. This was opposed by Lord Sudeley and Lord Campbell. The first pointed to the great success of Dr Reid's plans, and objected to superseding him and appointing in his place an individual "of whose knowledge of the science of ventilation they had no proof whatever." Lord Campbell, considering what Dr Reid had done, and that he had engaged, if they allowed him the necessary powers, to make the ventilation of the House of Lords as perfect as that of the House of Commons, "thought that it would be unfair to deprive him of the honour of carrying his promises into effect." Lords Lansdowne, Grey, and others, while voting for the change, fully admitted Dr Reid's success in

the House of Commons, and regretted that the delay that would arise prevented them adopting his plans. The Duke of Wellington, with that practical sagacity which so distinguished him, thought that the two Houses should act together with respect to this question. This step on the part of the House of Lords, was attended with most serious consequences. It was, in fact, the beginning of the end. Whatever inconveniences or delays might arise from want of harmony between the architect and the ventilator, still more would it be difficult to reconcile *two ventilators* in the same building. It added to the confusion, rather than lessening it; and Dr Reid mentioned afterwards, in illustration of the additional perplexity created, that there was one room which, from the arrangement of the flues, was actually subject, as to ventilation, to *both* of the conflicting authorities. Dr Reid earnestly protested against this withdrawal of a considerable part of the building from under his charge, and showed also, but without avail, how, in a building with all its parts so connected, it would interfere with the efficient ventilation of the remainder. When the new House of Commons came to be occupied, the ventilation was in an unsatisfactory state, very different, indeed, from what had prevailed during fifteen years in the temporary House. The members now judged of the ventilation of their House by the advanced standard to which they had been accustomed for so many years in the temporary House. Dr Reid had inured them to a perfection and luxury of ventilation they never before experienced, never dreamed to be possible. Dr Reid, at his own request, it is believed, was called to the bar of the House to explain matters. His explanation resolved itself, shortly, into the existence of a divided authority, and his not having the necessary control over the adjoining rooms, corridors, &c. The House was satisfied with his explanations, and it was a very general impression that his appearance at the bar had done him much good,

and that he would now be placed in a more independent position, and armed with powers to carry out his plans in an efficient manner. A Committee of the House of Commons, which in the year 1852 inquired into the whole subject, recommended that the ventilation of the whole building should be placed under the charge of one person only, exonerated Dr Reid's system from any blame for the failure of the ventilation in the new House, and distinctly pointed out that his original plan was for the ventilation of the whole building; that he had been deprived of the superintendence of the greater portion when the works were more than half completed, and that his success had been complete at St George's Hall, Liverpool, where his plans were carried into effect from the commencement to the termination of the structure.

During that year negotiations were entered into between Dr Reid and the Government to render his appointment permanent, and give him the requisite powers to carry his plans into effect; but the adverse influences prevailed, these negotiations were abruptly broken off, and his connection with the ventilation of the Houses of Parliament ceased. A small sum was given to him as some compensation for the loss which he had sustained. This is not the place to enter on such a question, further than to say, that it was the strong conviction of those friends who knew his whole career and the proceedings connected with his removal to London, that the sum awarded him was totally inadequate to compensate for the sacrifices he had made.

This was a severe blow. Dr Reid had given up his profession as a lecturer on chemistry in Edinburgh, and sacrificed the fairest prospects, to devote himself to this great work; he had been associated with it for nearly seventeen of the best years of his life, attending at the Houses night and day, while the House was sitting, for twelve years, and, in the midst of inconceivable difficulties and annoyances,

applying himself to his task with all that zeal, industry, and indefatigable perseverance which characterised him. He looked forward hopefully to the crowning of his labours by the successful operation of his plans in this great national edifice,—a result which, there can be no doubt, would have been fully attained if, as elsewhere, the requisite powers to carry them into effect had been granted to him.

But, although Dr Reid himself did not derive from his labours the benefit he might fairly have anticipated, they have not been lost to the public. He advanced the art of ventilation a great step. He first showed that, for efficient ventilation in certain large buildings where it is specially needed, an artificial power must be applied; that it was only by the application of an adequate power that ventilation could be placed under control, and that there should be arrangements for cooling, moistening, and purifying the air, as well as for warming it; and he first exhibited a thoroughly ventilated public building. Dr Reid might be removed, but his plans could not be dispensed with. In their main features they are still carried on. With some modifications in mere details, the essential parts of his methods are still in operation in the Houses of Parliament. An adequate power is employed to draw or force air through the building, and to regulate the ventilation according to varying circumstances; the air is purified, warmed, cooled, or moistened before entering the apartment where it is to be breathed; and injurious local draughts are avoided by breaking down the currents and diffusing them widely. One of the latest writers on ventilation (*Hay*—the "Laws of Atmospheric Action") states:—

"Dr Reid is made the scapegoat, on whose head all the supposed shortcomings are laid; but, after all that has been said and *done*, the doctor's arrangements, in all their essential features, are still and again in use."

What Dr Reid did for ventilation will be best appreciated

by considering its state before he took up the subject. Something has already been said as to the former condition of the air in the House of Commons. The following additional testimonies will throw farther light on the value of his labours:—

"It is impossible to forget that the efforts of many of our most distinguished English chemists have been directed to the same object with but partial success; and that to yourself belongs, almost exclusively, the merit of having applied chemical science to the improvement of the atmosphere of crowded buildings."—*The Right Honourable the Speaker of the House of Commons*, 1843.

"The most eminent philosophers had been consulted upon the subject, to no purpose, for a century. From the varying heat and cold of the old House of Commons, and from its fetid atmosphere, the health of the members materially suffered." "Under your direction the present House of Commons has been rendered quite perfect as to hearing, temperature, and ventilation."—*The Right Honourable Lord Campbell*, 1843.

"In the temporary House of Commons, Dr Reid had the merit of exhibiting, for the first time, an air-moving mechanism equal to the demand." "Until the late House of Commons existed, as ventilated by Dr Reid, there never was in the world a room in which 500 or more persons could sit for ten hours in the day, and day after day, for long periods, not only with perfect security to health, but perfect comfort. I think an important novelty was therein achieved."—*Dr Neil Arnott, Evidence before Committee*, 1852.*

* The following is extracted from the Report of the late meetings of the Social Science Congress at Edinburgh:—"Mr Heywood alluded to Dr Reid's method of ventilating the old Houses of Parliament, and expressed his regret that that gentleman had not been allowed to carry out his plans in the new Houses, which were badly ventilated. Mr Rawlinson said, that Dr Reid had been scandalously used in the matter of the House of Commons. There was, however, a good example of his style of ventilating buildings at St George's Hall, Liverpool."

It was Dr Reid who first reduced ventilation to scientific principles, and replaced the rude, imperfect, chance and unreliable methods which formerly prevailed, by a system certain in its action, obedient to control, and capable of being regulated. That our legislators can now remain for hours in their chambers, comparatively free from the close and 'fetid atmosphere,' violent draughts, headaches, and general oppression, from which they suffered so much in former times, is due mainly to the systematic and efficient arrangements for ensuring and controlling ventilation, and supplying them with a pure and healthful atmosphere, first introduced by Dr Reid.

While thus harassed with annoyances, vexations, and ultimate total disappointment as to the great work to which he had so long devoted his time, talents, and energies, he had the satisfaction, before he left England, of seeing his next greatest work brought to a successful termination —St George's Hall, Liverpool—where his system of ventilation was in operation in all its details. His plans had been introduced there at the request of the original architect, the late H. L. Elmes, Esq., with whom, as well as with his successor, Professor Cockerell, Dr Reid's intercourse had been uniformly pleasant and harmonious during twelve years of mutual co-operation. This fine edifice, one of the most elegant, as it is also one of the largest of the public buildings of England, contains a great number of different halls and apartments, having under one roof two large assize courts, minor courts, grand jury room, judges' private rooms, barristers' library and robing rooms, with a suite of witness and other rooms, a concert room, and a great hall, capable of containing about four thousand persons. The dimensions of the latter are,—length 169 feet, breadth 100 feet, height 86 feet.

All these can be brought at once, or in such portions as may be desirable, under the action of the ventilation ; and on

some occasions, 4500 persons have been in the building for a period of nearly ten hours; the air, by the admirable ventilating arrangements having been, during the whole time, supplied to that multitude in a pure state, and in a comfortable and agreeable condition as to temperature, moisture, &c. The power used is a 15-horse steam-engine, driving four fans, 10 feet diameter and 5 feet broad, and they can be so arranged as to act separately, or concentrated on one point. In the ventilating shafts furnaces are placed, to draw off the vitiated air, and are entirely controlled by valves. The movement of air is upward, but it can be reversed at pleasure. The air is washed before it enters the rooms, so that there is little or no dust. The opinions of engineers and others, as well as of those who frequently, and for hours at a time, are subjected to the action of the system, are entirely favourable. It has been, in part, working since 1851, the Assize Courts having been occupied then; the whole building was opened in 1854. Nothing can exceed the simplicity of the arrangement (to those who understand it); and as it is perfectly under control, any alteration is effected in an instant, either with reference to the increase or lowering of the temperature, application of moisture, or quantity of air supplied. The building is warmed by hot water and steam coils, the latter being used principally in extremely cold weather. The amount of air that can be supplied is from 30,000 to 50,000 cubic feet per minute, depending of course upon the numbers present.

The above details have been kindly supplied by Mr William Mackenzie, who has charge of the warming and ventilating at St George's Hall. A paper, describing the system, was read by him in August last, before the Institute of Mechanical Engineers, and it was the general opinion, that the ventilating arrangements were by far the most perfect in the kingdom. Mr Mackenzie states:—" Of our ventilating works, all I can say is, from practical experience,

nothing can be more perfect, and they are looked upon as the largest and most successful warming and ventilating arrangements in Europe,—so much so, that before any large building, either in this country or on the Continent, is finally arranged to be built, competent persons have been sent here to gain all the knowledge the works at this building can give them."

Such has been the result, where, as in the temporary House of Commons, Dr Reid had freedom to carry out what he regarded as essential for the effective working of his plans.

Ventilation, as conducted in the temporary House of Commons and St George's Hall, is one of the triumphs of practical science. Our political life and social customs lead us to assemble in confined spaces in hundreds or thousands, and remain there for hours together, each unceasingly poisoning the surrounding atmosphere, and liable to serious injury in health, if the poison be not removed with sufficient rapidity, if it be removed by violent local draughts, if the air around be too warm or too cold. It is, then, a public benefit to provide a sure means of removing the poison, as fast as it is poured into the air; of doing this so gently and equably, that chills from draughts shall be entirely avoided; of preserving the surrounding medium in a healthful state as to temperature and moisture, and thus enabling a dense crowd in a public hall to remain there as long as they choose in perfect comfort and perfect safety as to health. That is achieving something, and that Dr D. B. Reid first taught us how to do.

While resident in Scotland, and during the first few years after he settled in London, Dr Reid was much consulted as to the ventilation or improvement of the air in a great variety of buildings, private, as well as public, including St James' and Buckingham Palaces; and at this day, in numbers of places throughout the country, the benefits of his in-

genuity, skill and experience, are still enjoyed. His plans have been in successful operation in the prisons of Edinburgh and Perth for many years. Among other notable applications of his system may be mentioned, the ventilation of Her Majesty's royal yacht, the Victoria and Albert, and of the steamships of the Expedition to the Niger. The officers of the expedition acknowledged their strong sense of his unwearied exertions to execute the works in a very limited time, and of the thorough control over the air below decks given by his arrangements, by the presentation to him of a testimonial, accompanied by two pieces of plate.

In 1844, Dr Reid was selected as one of the Royal Commissioners for inquiring into the state of large towns and populous districts, and, along with Owen, Stephenson, De la Beche, and the other eminent men composing the commission, took part in the important inquiries which were instituted, and valuable Report, published in 1845.

In 1855, Dr Reid removed with his family to the United States. He delivered lectures at the Smithsonian Institution at Washington, at Boston, and other places, and was several times consulted by public bodies projecting sanitary reforms; but met few opportunities of being useful in the peculiar line in which he was eminent, till some time after the breaking out of the war. At last, early in the present year, the Government conferred upon him the appointment of Inspector of Military Hospitals, for which they judged his experience and acquirements peculiarly qualified him. But, like his distinguished pupil, Edward Forbes, he was cut off within a few months after he had attained a position fitted for the exercise of his talents and attainments. He died suddenly at Washington, in the course of a professional journey, of congestion of the lungs, on the 5th of April last.

Dr Reid was the second son of Dr Peter Reid, physician in Edinburgh, and Christian Arnot. Dr Peter Reid, through his mother, Elizabeth Boswell, was the representative of a

very old Fife family, the elder line of the Boswells of Balmuto, who acquired lands in that county, by marriage with one of the heiresses of Lochore, early in the reign of David Bruce. Dr D. B. Reid was the twelfth of the family, in different generations, who had borne the name of *David Boswell.* Christian Arnot was the eldest daughter of Hugo Arnot of Balcormo, a well-known advocate and antiquarian, as well as a man of great public spirit, who lived in Edinburgh towards the close of the last century. He was author of a History of Edinburgh, and a Collection of Scottish Criminal Trials. The Arnots of Balcormo were a branch of the Arnots of Arnot, who, for nearly seven hundred years, possessed the lands on the east bank of Lochleven, where Arnot Tower, a curious relic of bygone times, still rears its head, on the southern slope of Bishop's Hill. In 1834, Dr Reid married Elizabeth, second daughter of James Brown, Esq., merchant, Edinburgh, who, with five children, survives him.

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# HOWARD'S
# PATENT VENTILATOR.

A SCIENTIFIC INVENTION

OF CHEAP CONSTRUCTION,

APPLICABLE AT SMALL COST TO ALL

Buildings, Railway Carriages, Passenger Vessels, &c.

AND A

PERFECT MEANS FOR THE

INTRODUCTION OF PURE FRESH AIR,

WITHOUT DRAUGHT.

---

Patented in the United States under the name of the "Lesperance Ventilator."

---

1869

# HOWARD'S PATENT VENTILATOR.

## GENERAL REMARKS.

Ventilation is divided by writers on Hygiene into Natural and Artificial. The latter supposes the employment of some mechanical force such as heat, steam, water, horse or man power. Under the former is included any contrivance by which the best possible use can be made of the air with which nature supplies us. Such a contrivance is the Howard Ventilator.

It is hardly necessary to point out the necessity that exists for a constant supply of pure fresh air into Hospitals, Prisons, Schools, Barracks, and all public buildings and private houses, more particularly in winter when we are obliged not only to resort to artificial heat, but of necessity to use every means to exclude the cold atmospheric air. Who, in going from the fresh air into any Public Establishment in the winter time, has not immediately found a warm apartment, filled with a poisonous atmosphere? What is true of public buildings is equally true with regard to private residences. Every medical man has, in his practice, experienced the fearful results of the want of pure air, which he has no means of admitting to his suffering patient but by opening a pane of glass and allowing such a rush of cold, damp air into the room, as to do more harm than good. If any one requires more fresh air than another, it is the poor suffering *consumptive ;* yet from the want of a proper means for admitting pure air into the room, his sufferings are increased and his days shortened, housed up as he is in close rooms during the winter. How many of the deaths recorded every day, are easily traceable to the result of colds taken whilst sitting in a draught? Experience proves that more colds are taken in this way than in any other, in summer as well as in winter. The following extract from the Report to the Imperial authorities, made by Dr. Muir, Inspector General to the forces stationed in Canada, will prove how necessary to the public health is the proper ventilation of all buildings:

" Dr. Muir reports that great improvement was made in the year 1866 in the housing of troops in Canada. An excellent general hospital at Montreal has been substituted for the four line Regimental Hospitals formerly in use. Not only has a large saving to the public been effected by the change, but the sick are more comfortably accommodated. Whilst the troops everywhere are well housed, there is great difficulty in keeping the air in their rooms in a due state of purity during the winter. The ill effects of impure air are not very perceptible in private houses, where the inmates are few, but where 20 or 40 men are put in a single room, where they take their meals, as well as sleep for six or seven months consecutively, there can scarcely be a question that the seeds of grave disease, necessarily having connection between cause and effect, may not be at once traced. *Dr. Muir cannot help thinking that the large number of men treated and invalided for chest diseases during the five years he has been in this command, bears a close relationship to this impure state of barrack air.*"

Besides Ventilators for the admission of *pure air*, all buildings both public and private, should be well supplied with means for the escape of the *impure air* generated therein. The escape tube should be as high up as possible; chimnies, stove and pipe holes perform this duty in a manner, in private houses, but they do not act effectually, from the fact that the draught is formed close to the floor, instead of the ceiling, thereby exposing the occupants to draughts and chills.

Few persons can conceive the *amount of pure air necessary for health.* Parkes, the highest authority on the subject of Hygiene, lays down as a rule that 2000 cubic feet of fresh air per hour per head for persons in health, and from 3000 to 4000 cubic feet for the same time, for each sick person are required. In a table published by him he states that

"The amount of fresh air to be supplied per head per hour in temperate climates under the following circumstances is :

| | | |
|---|---|---|
| In Barracks | 1,059 | cubic feet by Day and 2,118 by Night |
| In Workshops | 2,118 | " " " |
| In Prisons | 2,118 | " " by Day and Night. |
| In Hospitals | 2,825 | " " " " |
| " " | 4,236 | " " during hours of Dressings. |
| " " | 5,650 | " " during Epidemics. |
| In Schools | 1,059 | " " |

Speaking of the impurities from our breath and the exhalations from our skin, &c., he makes the following remarks :

" An adult man in ordinary works gives off in 24 hours from 12 to 16 cubic feet of carbonic acid gas and also emits an indeterminable quantity of the same gas by the skin. In Hospitals, in addition to being vitiated by respir ation the air of sick rooms is also contaminated by the abundant exhalations from the bodies and by the effluvia from discharged excretions."

" That the breathing of air rendered impure from any cause is hurtful, and tha the highest degree of health is only possible where to other favorable conditions is added that of a proper supply of pure air, might be inferred from physiological evidence of the paramount importance of proper aeration of the blood. Experience strengthens this inference and statistical inquiries on mortality prove beyond a doubt, that of the causes of death which usually are in action, *impurity of the air* is the most important. Indeed, observation confirms this. The air must be removed so immediately that there shall be no risk of a person breathing again his own expired air or that of another person. In hospitals, especially, it is desirable that there shall be no chance of the air of one sick person passing over the bed of another; therefore the movement of the air should be rather vertical than horizontal, and as the expired air and all the exhalations from the body or bed clothes at first pass upwards from their levity, it is desirable that they should be discharged above and not drawn down again past the patient."

Speaking of Ventilation, Mr. Parkes says .

" In order to keep air in its necessary purity, it must be continually changing. Whatever way the air is supplied, certain conditions must be laid down; the air which enters must itself be pure, its movements must be *inperceptible*, otherwise it will cause the sensation of draught and will chill. It must be diffused all through the room so that in every part movement, shall be going on in other words the distribution must be perfect. A moving body of air sets in motion all air in its vicinity, it drives air before it and at the same time causes a partial *vacuum* on either side of its own path, towards which all air in the vicinity flows at angles more or less approaching right angles."

Mr. Parkes gives a description of the many modes invented for the transmission of pure air into buildings, but does not seem to have much confidence in any of them. Some of them are clumsy and useless and many very expensive. Amongst the number, are drilling holes in the panes of glass; having two panes, the outside open in the bottom, the inside in the top, the air to pass between the two panes; tubes passing into the room and perforated; air passing round hot steam pipes; pieces of board constructed in the upper part of the window to direct the air inwards and upwards; fine wire screens, &c., &c.

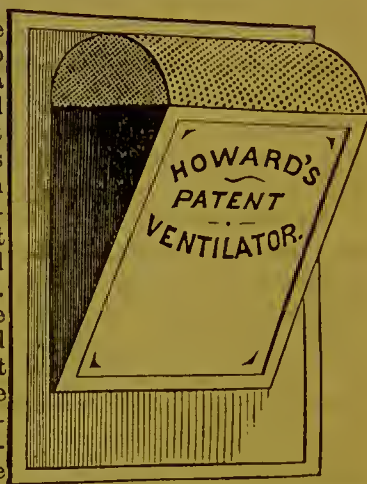
A Ventilator should always and at all times admit pure air; the air should be equally diffused all through the rooms, in fact the distribution should be perfect; its movements should be imperceptible, consequently without draught; the air should be rendered warm in its passage through the Ventilator; if there be any impure gas in the atmosphere, such as sulphurretted hydrogen, it should be absorbed in the machine before being admitted in the room; no suspended organic matter should be admitted with the air; and if the air is too damp (that is, saturated with

watery vapors), part of the water should be absorbed by a simple change in the Ventilator.

These were the advantages proposed in the construction of the Howard Ventilator, and which after numerous tests of the highest scientific authority, it is fully allowed to possess.

## DESCRIPTION, MANNER OF USE AND ACTION.

Fig. I.




The accompanying diagram (Fig. I) represents the interior appearance of the Ventilator. The air in the Ventilator has to pass through three plates of perforated tin, a covering of sponge or wool, and a box filled with charcoal. It is thus impossible that any suspended organic matter can pass through it, and when necessary, a portion of the damp in the air is absorbed and retained in the sponge or wool in the first chamber, and all impure gas is absorbed by the charcoal in the second chamber. The air is rendered warm, first by the amount of friction it has to undergo, and secondly by the chambers through which it passes being warmed by the heat of the room. From the formation of the Ventilator, the air passes upwards and inwards, *vertically* and not *horizontally*; therefore there can be no sensible draught; it is divided into numerous and continuous streams and is discharged into the room like water from a fine rose on a watering pot.

Fig. 2.

By reference to Figure 2, which gives a lateral view of the Ventilator, an idea will be gained of the mode of ingress, and purification of the air. A layer of sponge rests on a finely perforated plate of sheet metal. Above this compartment, and separated from it by a similar perforated plate is a layer of charcoal, which, as is well known, is a powerful absorbent. Over this is a perforated dome, through which the air finally enters.

The sectional view in Figure 3, will make the construction still more apparent. The Ventilator, as seen from the interior of an apartment, when placed in a window, is presented in Figure 4, and in Figure 5, there is an exterior view of it in the same situation.

It will thus be seen that the Howard Vintilator is as simple and tasteful, as it is soundly scientific, in its construction.

In every private house there should be one large or two small Ventilators in every large room, particularly in bed-rooms. In Hospitals, Barracks, Schools, Prisons, &c., there should be one large or two small ones,

for every twelve persons in the day time, and in the sleeping rooms, one for very eight persons. In prisons, one large Ventilator should be in each cell. The Ventilator should take the place of one of the highest panes of glass in the window, in houses already built; but when building, provision may be made to have it put in any convenient place, care being taken that no obstruction is allowed to prevent the easy withdrawal of the box of the Ventilator, when necessary to do so. The box of the Ventilator will of course face the inside of the room. Where double windows are used the funnel takes the place of the corresponding pane of glass in which the Ventilator is placed, and the funnel drawn out to cover the mouth of the Ventilator. When necessary to deprive the air of part of the aqueous vapor (damp) the sponge must be placed in the vacant chamber under the box, and should the wind blow very strong and cold, directly on the mouth of the Ventilator, the piece of flannel must be placed over the top of the box. At other times it is allowed to hang down. Unless the air be over wet, the sponge should not be used. As was stated above, the box as well as the whole of the Ventilator, should be dusted occasionally.

*Fig. 3*


When the Ventilators are used for Railroad Cars, they must be in the cars. Their size will depend upon that of the car, and they can be put in such places as may be deemed best by the builder; only that care must be taken that the tubes for the escape of foul air generated in the cars, *must be below* the Ventilator, otherwise the fresh air as well as the foul air, would pass through, and the object intended to be gained would be lost. By this plan the fresh air will displace the foul air and force it out through the escapes.

The sponge or wool should be always in use in railroad carriages. Every builder of a car may arrange these Ventilators to suit his own taste; but *the principle* laid down must be adhered to.

It may be objected to the Ventilator that it disfigures and obscures a window. The obscuration is very slight and the apparatus may be so beautified in various ways as to be made even ornamental. A handsome grating outside and a covering of carved wood inside, or, in fact, any plan suggested by the taste or consistent with the means of the person using it, might be adopted to remove its supposed unsightly features. Most persons, however, will admit that the inventor has been admirably successful in uniting beauty with usefulness in its construction. Any fancied disadvantages of this kind will have a very subordinate value, when set side by side with the inestimable gain of renewed life and health, which is the boon of a perfect system of ventilation.

The Ventilator might be very conveniently placed over a hall or back

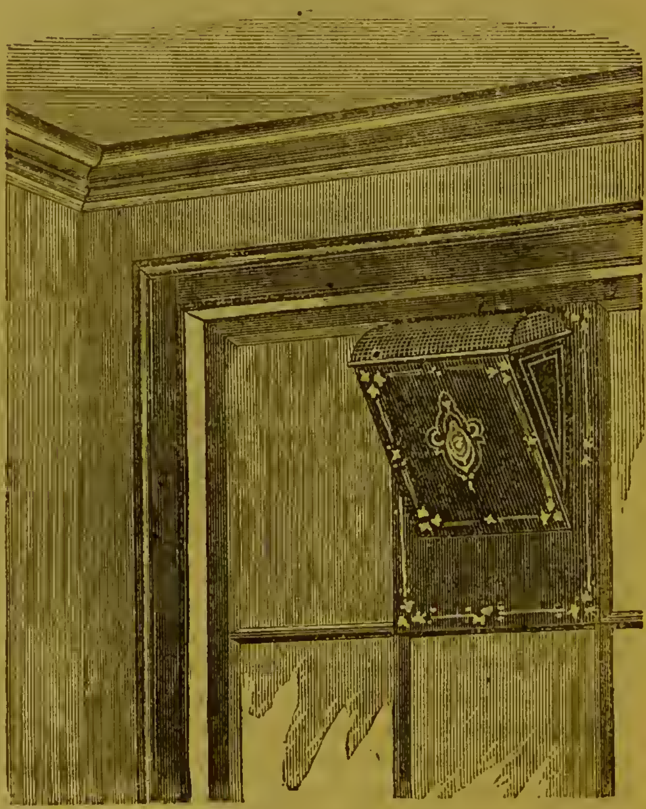
door where there is glass. In building, the windows of a house may not be used at all, but the Ventilator may be placed in the wall of the house, having the opening to the inside in the cornice ; and, in this case, the entrance or outer side may be covered with grating.

There is not the slightest doubt that if the Ventilator be used according to the directions given, there will be no difficulty in supplying either buildings or railroad cars with pure fresh air without any sensible draught.

## TESTIMONIALS TO THE EFFICIENCY OF THE HOWARD VENTILATOR.

The Howard Ventilator has undergone the test of experience in both public and private buildings, and under the most trying circumstances, both in Canada and the United States, and has received in both these countries the highest encomiums from persons of experience in practical hygiene. The opinions which are subjoined are the recorded results of actual trial.

Fig. 4.



# EXTRACT FROM A REPORT OF A SPECIAL COMMITTEE ON THE HOWARD VENTILATOR.

Presented at the Regular Meeting of the "New York Association for the Advancement of Science and Art," at Cooper Institute, and unanimously adopted March 8th, 1869.

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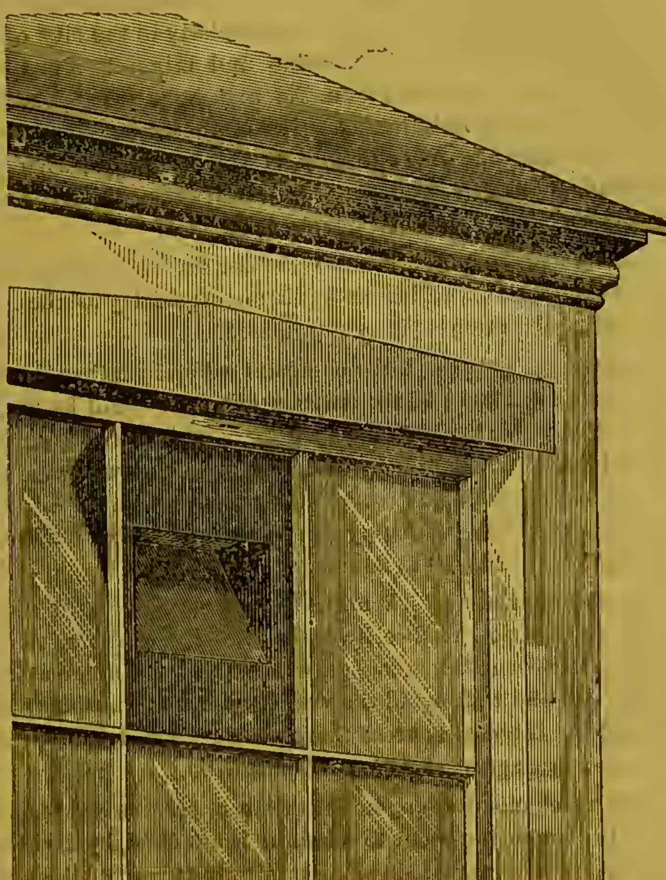
New York, 8th March, 1869.

To the Association for the Advancement of Science and Art.

Fig. 5.



The undersigned Committee, appointed at the last meeting of the Association to prepare a report on the Ventilator then exhibited, have given the subject a careful and minute consideration and hereby present our views thereupon.

With regard to the importance of removing from occupied apartments the foul gases which are universally and continually generated by respiration, perspiration, and various other vital functions, also by the combustion of gas, oil, and fuel, there is a very general conviction thereof, and several methods have been suggested, and are in practice for said purpose; but another equally important consideration has very recently received appropriate attention, viz. : *the supply of an ample amount of pure air.* It is a well understood philosophical fact that the removal of the air of any room is imprac-

ticable without the supply of an equivalent amount from without, and as this latter idea is very rarely practical, because of the general apprehension of danger derivable from *currents* of air, it is very seldom that a consistently and thoroughly ventilated building, either public or private, or any railroad car, or passenger vessel, is ever seen.

Another circumstance which frequently prohibits the supply of air from without, into occupied apartments, is the impurity of the general atmosphere in large cities, and some other localities where foul gases are produced by various manufactures, and deficient drainage and sewerage; also the emanation of disease-producing influences from the soil and vegetations of many rural localities. Of the latter sources of sickness there are some almost universally understood, for example, the sources of intermittent, typhus, and yellow fevers, rheumatism, catarrhs, consumption, and various others derived from impurities of the blood, caused by the inhalation of foul air.

One of the most copious sources of disease, particularly in crowded cities as we have for many years noticed especially in the city of New York, is the prevalence of *dust*, of both vegetable and mineral composition, derived from the filth of the streets, and from the numerous discreditable practices of both private and official individuals. The breezes raise immense clouds of it into the atmosphere, and drive them into the buildings, whereby all individuals, both outdoors and indoors, inhale the dust to a considerable extent, thus causing very numerous cases of physical disease.

To this subject neither our civic nor sanitary authorities appear to have given any attention, although by them, especially by the Board of Health, the evil might be almost entirely suppressed.

Heretofore we have had no means whereby either the dust, the poisonous gases, or the moisture of the outer atmosphere could be prevented from entering the doors or windows, the opening of which are the only means of supplying the interior of the house with fresh air. But we have now the pleasure of being able to say that the apparatus upon which we have been requested to report, is very clearly a happy arrangement for the purification of the atmosphere before entering into houses.

Its mechanical and chemical arrangement present a very good assurance that its application to dwellings, churches, hospitals, schools, railroad cars and all other occupied premises, will supply the inmates thereof with nothing but *pure air*, and thus avoid the very numerous atmospheric causes of disease, provided the internal sources thereof are removed by appropriate ventilation which this arrangement will greatly facilitate.

The mechanical arrangement of the apparatus causes a very free distribution of the air in the room to which it is attached, by dividing the current into a very great number of singularly minute streams, thereby totally obviating the objection against *currents of air*, but at the same time supplying the amount necessary for any number of persons, provided the room is sufficiently furnish-with the apparatus. One of its physical arrangements also causes the absorp-

tion of the moisture of the atmosphere, thereby preventing its entrance into the rooms. Also, as one branch of its structure is within the room, the coldness of the outer air may be reduced before entering.

The impure gases very frequently generated outside of houses are also arrested in the passage of the air through the apparatus, by being brought in contact with appropriate chemical materials, which absorb the gases, thus, happily preventing their foul influences. The most common sources of sickness of this nature being *carbonic acid gas*, and *sulphurretted hydrogen gas*, the latter, derived partly from gas manufactories, may both be absorbed by the chemical contents of the apparatus ; and what is equally important as a sanitary regulatian, no dust or other organized matter can pass through it, though the existence thereof in large cities might be almost wholly prevented by proper restrictions enforced by the sanitary authorities.

The enormous existence of this organic poison in the outer air causes its entrance into every house, thereby covering the furniture and clothing of the inhabitants, and also mingling with the articles of food, besides its inhalation into the lungs.

Almost every store and market make a display thereof on their saleable articles, and it may also be frequently noticed in our Croton Water, probably being derived chiefly from its absorption in the reservoirs. If the existence of this nuisance is not entirely suppressed by the appropriate authorities, as it might be, the owner of every house and every rail road car should prevent its introduction therein by such an efficient and simple means as the subject of this report.

Your Committee deem it likewise appropriate to refer to another well-established anti-hygienic circumstance, viz : that Cholera is carried into the air by means of organized matter, and that such is also the case with many eruptive diseases, especially Small Pox, Scarlet Fever, and Measles, the emanation from the surface skin in these cases being carried through the air, and hence become the sources of the spread of all these dangerous complaints.

The apparatus referred to, it is believed, would be found a protection of dwelling against the malarious sources from the outside.

Your Committee, after careful examination and mature deliberation, are convinced that this new Ventilator will perform all that the inventor proposes it should do, and we hail with great satisfaction this addition to science and art, considering that it will be found one of the best means for the preservation of health, and its restoration to diseased bodies, especially in hospitals.

Having thus become perfectly convinced of the value of this very happy arrangement of mechanical and chemical means for the purification of the chief source of vitality for every animal creature, and also for the avoidance of the very numerous sources of disease derived from the decomposition of many natural substances, and also from erroneous habits of large numbers of

the human race, your committee deem it appropriate to urge upon the proprietors of all occupied premises, especially the managers of schools, churches, hospitals, asylums, prisons, tenement houses, public vehicles of every description, and all passenger vessels, the application of this apparatus thereto, thereby assisting in the preservation of health, the cultivation of both mental and physical strength, and prolongation of human lives.

Respectfully submitted,

JOHN H. GRISCOM, M. D.
JOHN ALLEN, D. D. S.
JOHN JOHNSON.

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## EXTRACT FROM THE MINUTES OF A MEETING OF THE POLYTECHNIC ASSOCIATION OF AMERICAN INSTITUTE HELD AT THEIR ROOMS, NEW YORK, 15TH APRIL 1869.

Dr. Dubois D. Parmalee in the chair. At the meeting the Howard Ventilator was exhibited and its construction and utility explained.

Mr. J. Disturnell said that this apparatus had been presented to another scientific society in this city, and they had appointed a committee to examine it, who made a very extended and favorable report on it. In his opinion the influence which caused consumption would in a great measure be absorbed by this apparatus. In preventing diseases that are climatic, this invention is very valuable.

Dr. Edwards remarked that the Ventilator had been recommended to the Board of Health as a means of preventing disease, but unless ample means were provided for the egress of the foul air, the instrument would fail. What consumptive people want is air, pure natural air, not artificially made.

The patients at the Brompton Hospital, where the air is warmed, did very well, while they remained there, but when taken back to the cold air they died. But now we send consumptive people to the clear bracing air of Nebraska, and they come back well and remain so. The screens through which the air has to pass in this Ventilator acts on the principle of the Respirator described at a recent meeting. The force of the entering air can be regulated by the number of screens. To call this a Ventilator seems to be a very imperfect definition of it, as it effects many other objects as well. Its adoption by the Board of Health is a very desirable matter.

The Chairman remarked it was not only a Ventilator, but a filterer of the air as well.

Mr. J. A Whitney remarked that in cities and on the banks of streams this system of Ventilation would be very requisite.

Mr. J. R. Fisher said that it was a barbarism to have dust in the streets, but while we have it there must be something done to mitigate the evil, and that can be done by straining the air. This invention is especially valuable to those who have not the means of paying for luxuries.

## OPINION OF DR. SMALLWOOD, PROFESSOR OF METEOROLOGY, McGILL COLLEGE, MONTREAL.

" I have carefully examined Dr. Henry Howard's Patent Ventilator, having placed one for that purpose in a suitable position, and having submitted it for a considerable time to various experiments, with the aid of the thermometer, hygrometer, and ozonomoter, and having thoroughly tested it, am of opinion that it is a most perfect Ventilator, peculiarly adapted for the admission of *pure air* into any place ; freed, by its peculiar construction, from deleterious gases, and from too abundant amount of moisture. It is also furnished with the means of regulating the amount of air admitted.

" For the sick room, hospitals, railroad cars, and for private dwellings, where the admission of pure air is so important, the Ventilator will be found an object of great value ; and, I feel assured that so soon as it is more generally known, it will be universally adopted.

"Charles Smallwood, M. D., L L. D., D. C. L.,
"Professor of Meteorology in the University of
"McGill College, Montreal."

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## PROF. JOSEPH HENRY, OF THE SMITHSONIAN INSTITUTE, WASHINGTON CITY,

One of the very highest authorities on the subject of Ventilation, states in a paper that he has examined the Howard Ventilator, and is favorably impressed with "the importance of the invention, and is convinced that it may be employed with good results, particularly in sleeping rooms and in houses situated in malarious districts." He authorizes the publication of his approval of it.

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## THE BOARD OF INSPECTORS OF PRISONS AND ASYLUMS, FOR THE PROVINCE OF QUEBEC,

In their Report for 1868 speak as follows of this Ventilator:

### VENTILATION,

[Translated from the French.]

" All the prisons, except that of Quebec, are, more or less, deprived of this powerful agent in the preservation of health.

"This subject, so important in a sanitary point of view, has not received the attention which it merits, from the architects of this country.

"Formerly very little attention was paid to ventilation in public buildings, houses of education, hospitals, jails, &c.

"For some years past, however, many men of science have given the subject serious thought, and in this respect, as in many others, have made numerous researches.

" Every one, now-a-days, is convinced that ventilation ought never to be

lost sight of in the construction of buildings intended for the accommodation of large numbers.

" To satisfy this requirement many systems, answering more or less the end in view, have been put on trial.

" Of these systems, there are some whose application is difficult and expensive; others are remarkably simple—which does not prevent them from being every way suitable.

" During our visit to the St. Johns Asylum, we had occasion to examine a very simple apparatus, the invention of the able Superintendent, Dr. Howard, by means of which ventilation works admirably. This apparatus, which costs little, consists of a little box of tin, the interior of which is peculiarly made, is fixed in a window. The outer air is introduced transversely into the apartment, at the same time, getting rid of damp and all alien substance; so that it is circulated without sensible impression on the inmates. By this means, twenty-six thousand four hundred feet may be introduced hourly, enough for twelve persons in health and for six hospital patients. If one of these apparatus is not sufficient, it is easy to use as many as may be required.

" As far as our knowledge extends, we believe that this discovery is very useful, and that the apparatus ought to be used whenever ventilation is required. And, certainly, it is required in Prisons, Asylums, Hospitals, Educational Establishments, &c."

Dr. L. L. C. Desaulniers, President of the same Board, makes the following statement in the Book of the St. Johns Asylum.

" The apartments are to-day, (June 2nd,) notwithstanding the great heat, free from any unpleasant smell. This is, without doubt, owing to the good system of ventilation which has been introduced into the establishment—the invention of the zealous Superintendent, Dr. Howard.

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## EXTRACT FROM REPORT OF J. M. FERRES, ESQ., LATE INSPECTOR OF PRISONS AND ASYLUMS FOR CANADA.

" The St. Johns Asylum is kept in an admirable state of cleanliness. Were it not, it would be impossible for Dr. Howard to maintain it as free from sickness as as it is. He continues to devise expedients for improving the ventilation so that *almost as soon as foul air is generated it is expelled.*"

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## BOARD OF HEALTH, NEW YORK CITY.

This "Ventilator" was tested in one of the rooms in the Metropolitan Board of Health building, New York City, and was highly approved of both by the Superintendent of the Board, and the different gentlemen forming the Sanitary Commission.

## THE SCIENTIFIC AMERICAN

This distinguished organ of American invention, in speaking of the Ventilator, thus records its opinion of its merits: "This Ventilator is constructed upon sound scientific principles, and the employment of well known and thoroughly proved means to accomplish the ends sought, will give confidence to their tasteful combination, as used in the apparatus.

"It will be seen that the air enters this Ventilator by virtue of the pressure of the external air, the specific gravity of the air inside an occupied and warmed room being less than that outside. Hence it is not subject to being affected by external winds as much as many other kinds of apparatus. It appears to us to be one of the most important devices yet invented to secure ample and perfect ventilation in public school buildings, hospitals, churches, and private dwellings.

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## THE NEW YORK ASSOCIATION FOR THE ENCOURAGEMENT OF SCIENCE AND ART.

The "Howard Ventilator" was exhibited to the New York Association for the Encouragement of Science and Arts, and a committee was appointed to investigate its merits, which made a very favorable report. The following extract from this report sufficiently sets forth the views of this committee.

"Your Committee, after careful examination and mature deliberation are convinced that the Howard ventilator will perform all that the inventor proposes it should do, and we hail with great satisfaction this addition to science and art, considering that it will be found one of the best means for the preservation of health, and its restoration to diseased bodies, especially in hospitals."

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## THE SOCIAL SCIENCE CONVENTION.

At the meeting of the Social Science Convention at Albany, N. Y., in February, 1869, Dr. Griscom read a paper in which the merits of the Howard Ventilator were fully dwelt on. The speaker said that the object of the Ventilator was seven fold: 1. To admit air at all times. 2. To cause it to move transversely, and not horizontally. 3. To diffuse it equally into all parts of the apartment. 4. To prevent suspended organized matter from passing in with the air. 5. To free the air from carbonic acid and sulphuretted hydrogen gas 6. To absorb the excess of aqueous vapor with which the air may be surcharged. 7. To prevent drafts in the admission of the air.

INSTITUTION

OF

# MECHANICAL ENGINEERS.

PARIS MEETING.

1867.

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ON THE

# VENTILATION OF PUBLIC BUILDINGS.

BY GENERAL MORIN,

MEMBRE DE L'INSTITUT.

# ON THE VENTILATION OF PUBLIC BUILDINGS.

By GENERAL MORIN.

The renewal of air in buildings is only rendered necessary by the vitiation resulting from the respiration and exhalations of the occupants, and by the accumulation of the products of combustion from artificial lighting; and the writer has been led by his own observations and the consideration of the results obtained by others to the following conclusions as to the principles on which the ventilation of buildings should be based:—

*First*—Ventilation consists in getting rid of all vitiated air and replacing it by fresh air.

*Secondly*—The principal object of ventilation is to get rid at once of all vitiated air. It ought to be removed in general from the point nearest to the place where the vitiation takes place, in order to prevent any further diffusion into the room; and on the contrary fresh air ought to be introduced at the point furthest removed from the occupants of the room.

*Thirdly*—The different arrangements that proceed by *Suction*, when well proportioned and well carried out, are more effectual than those which depend exclusively on blowing in the fresh air, as the latter do not in every instance and at all times ensure the vitiated air being uniformly and continuously expelled.

*Fourthly*—The quantity of fresh air required, whatever may be the height from which it has to be drawn, and whatever the quantity, can be obtained by suction alone, and without the aid of any blowing apparatus, by giving to the inlet openings for the fresh air sufficiently large dimensions, and by suitable arrangement.

*Fifthly*—Suction can easily be obtained either by means of the ordinary open fireplaces with chimneys or similar heating apparatus, or by means of special fireplaces placed at the bottom of the

exhausting flues and acting as auxiliaries when the rooms are large. The air to be removed ought to flow towards the bottom of these fireplaces, and wherever possible by means of special air flues leading from openings close to the sources of vitiation.

*Sixthly*—Ventilation by suction by means of fireplaces and chimneys can be adapted to the proportions and arrangements of every kind of room, as it resembles the ordinary and natural ventilation of rooms, and the volume and temperature of the fresh air supplied can be varied as required. It only requires the construction at a small expense of fireplaces with their chimneys, and of air flues, which when once constructed cost but little to keep up; and also the regular feeding of the fireplaces, which any common attendant is competent to do. On the contrary, ventilation by means of blowing or other mechanical apparatus necessitates, besides the flues and chimneys common to both systems, the addition of blowing machines and engines with special air passages, special artisans, engineers, and firemen, and involves an extra cost for keeping up.

*Seventhly*—In hospitals with several stories, the blowing-in system does not afford the same guarantee as that of suction against the diffusion of the vitiated air from one room to another through the openings of the discharging flues, when it happens that the pressure and movement of the air of the room is disturbed by the opening of doors and windows.

Suction produced by simple fireplaces and chimneys, with sufficient area of opening for allowing the fresh air to replace the vitiated air, and without any mechanical apparatus, is consequently the most desirable means in the writer's opinion for effecting the ventilation of buildings, except in rare cases; and where special circumstances may necessitate the forcing in of fresh air by mechanical means, the action of a strong suction should also be added. This necessity never occurs in buildings where a continuous supply and removal of a nearly uniform quantity of air is required, but only when on the contrary this service has to be varied frequently between different portions of the same building, and when the quantities of air to be removed differ greatly from one day or from one hour to another; as in the case of the St. George's Hall, Liverpool, where mechanical

ventilation exclusively is adopted, and the quantity of air required varies in the extreme proportion of 1 to 50. In such cases it may become necessary, or at least useful, to employ mechanical apparatus in addition to the action of suction, in order to ensure a sufficient supply of fresh air.

The following proportions for the quantity of air required to be supplied per hour for each person are based upon the results of a large number of experiments by different observers, and though higher than the rates formerly adopted are not in the writer's opinion at all exaggerated :—

| | | |
|---|---|---|
| Hospitals for ordinary patients . . | 2000 to 2400 | Cubic Feet. |
| Ditto, in cases of epidemic . . . | 5000 | ,, |
| Workshops, ordinary trades . . . | 2000 | ,, |
| Ditto, unhealthy trades . . . | 3500 | ,, |
| Prisons . . . . . . . . | 1700 | ,, |
| Theatres . . . . . . . | 1400 ,, 1700 | ,, |
| Meeting Halls . . . . . . | 1000 ,, 2000 | ,, |
| Schools for Children . . . . . | 400 ,, 500 | ,, |
| Ditto, Adults . . . . . | 800 ,, 1000 | ,, |

The temperature of the air in places abundantly ventilated, and having a continuous renewal of the air, can be allowed to be maintained at a higher point than in rooms not well ventilated; but as a general rule the temperature should not exceed, in

| | | |
|---|---|---|
| Hospitals . . . . . . . . . | 61° to 64° | Fahr. |
| Workshops, Barracks, and Prisons . . . . | 59° | ,, |
| Schools . . . . . . . . . | 66° ,, 68° | ,, |
| Meeting Rooms . . . . . . . | 66° ,, 72° | ,, |
| Theatres . . . . . . . . . | 68° ,, 72° | ,, |

The fresh air supplied should be at nearly the same temperature as the one to be maintained in the room; but this has to be increased to as high as 85° or 95° Fahr., if there is a large cooling surface of glass; or to be diminished where the room is heated by a large number of lights or a large concourse of persons. For the purpose of regulating the temperature, the supplied air, warmed by some heating apparatus, has to be received first into a chamber into which cold air can be introduced for mixing with it.

The following relations between the volume and temperature of the air and the areas of the air flues have been obtained from theory and practice combined :—

$$V = C\sqrt{(T - T')\,H}$$
$$Q = CA\sqrt{(T - T')\,H}$$

In which $A$ = sectional area of the exhausting flue.
$H$ = height of exhausting flue.
$T$ = average temperature of air in flue.
$T'$ = temperature of external air.
$C$ = coefficient, constant for each air flue as regards its proportions and arrangement.
$V$ = average velocity of air in the flue.
$Q$ = volume of air passed per second.

The results derived from these relations are that the velocity of the escaping current is proportional to the square root of the excess of the temperature of the heated air in the flue over the external air, and also to the square root of the height of the flue or chimney ; and the volume of air extracted is consequently proportional in addition to the sectional area of the flue.

The position of the openings for the admission and removal of the air is a point of great importance ; and none of these should be made at the level of the floor, as is too often the case, because they are then exposed to obstruction by sweepings and rubbish from the floor. The openings for the admission of fresh air, whether warm or cold, should be placed near the ceiling, or at such a height that no person may receive the impression of a draught. The openings for the abstraction of the air should on the contrary be placed generally in the lower part of the room.

The velocity of the air should continually increase through the several passages of the building, from its entrance to its final discharge, which is best effected by the use of a single shaft for taking off the air from the whole building ; and the velocities should be about—

| | | | |
|---|---|---|---|
| 2·3 to 2·9 | feet per | second | at the entrance |
| 3·3 „ 3·9 | „ | „ | in the first passage |
| 4·3 „ 4·6 | „ | „ | in the second passage |
| 5·9 „ 6·6 | „ | „ | in the discharging shaft. |

These speeds can be easily obtained in most cases by an excess of 35° to 45° in the temperature of the discharging shaft over the external air, except in the case of theatres, where a difference of 95° to 105° is required, on account of the complication of the passages. With the supply openings in the ceiling, so that the air descends vertically, the velocity of the entering current should not exceed 1·6 feet per second; but when the air enters at the sides of the room at a considerable height the velocity may be as high as 3·3 feet per second without causing inconvenience. The plan of ventilation by suction has been objected to as causing objectionable draughts of air when doors are opened communicating with the exterior; but this sensation of draughts is got rid of when suitable proportions are adopted, and when care is taken that the passages communicating with the exterior are suitably warmed. The ordinary chimneys of houses produce in many cases a sufficient abstraction of air even without a fire, from the ordinary difference of temperature between the internal and external air; and this ventilating power can easily be increased by introducing into the chimney a vertical pipe containing a few gas burners.

An example of the application to a large building of the principles of ventilation described in the present paper is shown in the accompanying diagram, Fig. 1, which represents the Public Schools in the Rue des Petits Hotels in Paris. This building contains an elementary school for 400 children, and a drawing school for 270 pupils. The ventilation is at the rate of 350 cubic feet per hour per person, and the warming is effected by two heating stoves with vertical tubes. The warmed air is supplied to each storey by three vertical channels, which discharge into a long wide passage extending the whole length of the rooms, and into this passage external cold air can be admitted to regulate the temperature. The supply of air flows into the rooms horizontally near the ceilings.

The rooms of the drawing school are open at night, and offer special difficulties in ventilation, from the large number of gas burners in use. The plan of abstracting the vitiated air close to the floor cannot be exclusively applied in this case, as it would cause the

discomfort of pouring down air of 85° to 95° temperature upon the heads of the occupants. It is necessary therefore in this case to allow the heated gases from the combustion of the lights to escape through openings in the ceiling, but at the same time fresh air is made to enter at the sides near the ceiling. In such cases, when the room has not attics above it through which the outlet openings in the ceiling can discharge, special flues are required to be made for this purpose, and these should be situated as far as possible from the points where the admission of fresh air takes place. By means of this plan of ventilation the temperature of the above rooms has been maintained until 10 o'clock at night at 71° at a height of 5 feet above the floor, and at an average of 75° near the ceiling; but before this plan was adopted these temperatures were 80° and 91° respectively.

The discharge openings should be made along both of the longer sides of the room, and should be as numerous as possible, and their total effective area should be such as to limit the velocity of the air passing through them to 2·3 feet per second. They should communicate with descending passages, converging below into a main discharge passage leading to the bottom of the discharging shaft. The chimney pipe from the hot air stove is made to pass up this shaft for assisting the draught, but a small fire at the bottom of the shaft is also requisite.

An example of the ventilation of a large meeting room is shown in Fig. 2, which represents the Lecture Theatre of the Conservatoire des Arts et Métiers (in which the present meeting is held) and in which the ventilation arrangements have been carried out by the writer, and have been satisfactorily working for the last four years.

The vitiated air is taken off through orifices made in the risers of the steps, opening into the space below the seats, which communicates by an outlet passage with the discharging shaft; the requisite draught is maintained in the shaft by means of a fire at the bottom, dampers being placed in the passage to moderate the current of the air. The supply of fresh air is introduced from a chamber in the roof, and enters the Lecture Theatre by openings distributed over the surface of the ceiling.

In such buildings the ventilation should provide an amount of 1000 cubic feet of air per hour for each person, and the area of openings for the abstraction of the vitiated air should be sufficient to prevent its velocity through the openings exceeding 2·3 to 2·6 feet per second, the openings being distributed as uniformly as possible over the whole of the steps. The velocity of the air in the outlet passage should not exceed 3·9 feet per second, and the velocity in the discharging shaft should amount to 6·6 feet per second in order to ensure the stability of the current.

The inlet openings for supply of fresh air, when situated in the ceiling, should have such an area as to allow the velocity not to exceed 1·6 feet per second; in this Lecture Theatre, where the total quantity of air admitted reaches 170 cubic feet per second, the area of openings slightly exceeds the above proportion. When it is requisite in such places for the inlet openings to be at the sides, they should be situated on two opposite sides, and as high from the floor as practicable.

The air introduced for ventilation should in winter have a temperature of $3\frac{1}{2}°$ below that maintained in the Lecture Theatre, which should be about 68°. As such places require to be ventilated only when occupied, it is necessary to have the means of warming them by special orifices, in addition to those which supply the ventilation.

The ventilation of a large theatre is illustrated by Fig. 3, representing the Théâtre Lyrique in Paris, in which the principle of the writer's plan of ventilation was adopted; but this was unfortunately only partially carried out in the details, so that the full advantage is not realised in the results.

The number of seats in this theatre is 1470. For the ventilation of the stage and its dependencies, special means have to be applied by an auxiliary discharge flue above the stage, intended for use when required to remove any large quantities of smoke from extensive illuminations. In the body of the house, where the maintenance of a constant ample ventilation is required, there should be a supply of fresh air of 1400 cubic feet per hour for each person, with the means of increasing this in summer to 2000 cubic feet per hour. It is

important for the supply of fresh air to be obtained from open spaces or gardens, if possible, or else by special shafts bringing the air from a point above the buildings, and far removed from the outlets of vitiated air. In the case of the theatre shown in the diagram, the inlet for fresh air is made in the square of the Tour St. Jacques, by means of a well 11½ feet diameter, communicating by a tunnel of the same area with the space under the theatre that is occupied by the warming apparatus and the mixing air chambers. The velocity of the current in the inlet passage was ascertained to be 3·08 feet per second in a special examination that was made some years since, and the sectional area of the passage being 97 square feet, the volume of fresh air admitted amounted to 300 cubic feet per second, which was somewhat in excess of the quantity that the apparatus was designed to supply. This area of inlet however has subsequently been allowed to be contracted considerably by the growth of ivy at the entrance.

The admission of the fresh air to the body of the house takes place between the floor joists or through the false bottoms made under the floors of each of the rows of boxes and galleries, as shown in the diagram, Fig. 3, the air entering horizontally all round the theatre through these spaces, which should not be less than 5 to 6 inches clear height. The fresh air is also admitted by openings from about 10 feet height in the vertical walls on each side of the stage, and also by auxiliary channels under the flooring of the passages, intended especially for extra summer ventilation, and controlled by valves. For preventing the occurrence of unpleasant draughts upon the opening of doors into the exterior passages, these passages have to be warmed to a temperature of about 68°, and inlets of warm air are provided opposite the different doors in the passages.

A portion of the air, on entering by the main inlet passage, is warmed by traversing two sets of heating apparatus placed in the basement, as shown in the diagram; and the remainder is delivered into mixing chambers for regulating the temperature of the air supplied in the building. The area of passage through the heating apparatus is ·97 square feet, and the volume of warm air supplied 245 cubic feet per second, giving a velocity of current of 2·5 feet per second.

The vitiated air is taken off through numerous openings in the lower part of the sides of the boxes and passages, and in the risers of the steps in the gallery, each box or pair of boxes having a separate discharging flue; and the total area of these openings has to be such as to allow the velocity of the air not to exceed 2·3 to 2·6 feet per second. The exhausting flues from the several tiers of boxes are made to rise towards the dome above the chandelier, those from the pit, orchestra, and boxes on the ground tier, being carried below the floor into main flues leading to vertical shafts, as shown in the diagram; and the area of these exhausting passages should be such as to give a velocity of current of 3·3 to 3·9 feet per second. In the pit and orchestra, outlet gratings should be placed all round the sides, and in the sides of the air passages underneath the seats; these outlets open into a space left under the floor, which leads to the main discharging shaft on each side, this space being divided accordingly into two portions. These outlet gratings should not be placed in any case in the floor, as was done in this theatre, contrary to the writer's intention.

The cast-iron chimney pipes from the heating apparatus are carried up the exhausting shafts to aid the draught, the pipes being kept isolated throughout; and a small firegrate is placed at the bottom of each shaft, for use when extra ventilation is required in summer. The area of these exhausting shafts is required to be such as to give a velocity of current of 5·6 to 5·9 feet per second; and they should all lead, when possible, to the dome over the centre of the theatre, into which the outlet flues from the upper tiers of boxes also discharge. It is best for a general outlet shaft to be built of brick (not metal) above this dome, and to be carried at least 20 or 25 feet above the top, the area of this shaft being such as to give a velocity of current of about 6·6 feet per second.

A series of experiments on the ventilation were made on five successive nights in May, 1863, with the external temperature ranging between 56° and 74°; and the result obtained was that with an average consumption of 4 cwts. of coal per night, costing 7*s.* to 8*s.*, the removal of 166 cubic feet of air per second

was effected, amounting to 1400 cubic feet per hour per seat of the pit and orchestra. With this ventilation the temperature of the house can be maintained within comfortable limits; but this extent of ventilation is unfortunately not employed, as the intended use of the two large exhausting shafts is not carried out. The experiments made at the same time on the ventilation of the boxes showed that an abstraction of 377 cubic feet of air per second was effected by the centre shaft over the dome, amounting to 1800 cubic feet per hour per seat. The actual average ventilation for the whole house during the five evenings was found to be 1230 cubic feet per hour per seat. By this uniform ventilation the temperature in the different rows of seats was maintained most remarkably constant, the average temperatures in the first and fourth tiers being 68° and 70° respectively, when the external temperature was 52°; and when the latter was 70°, their temperatures were 78° and 81° respectively: in other large theatres however, which are not so ventilated, these temperatures are not unfrequently as high as 95° to 105°.

At another trial in November 1863, when the external temperature was as low as 39°, the temperatures within the house were found to be maintained at

| | | | |
|---|---|---|---|
| 66° | on | the | Stage. |
| 71° | in | ,, | Orchestra Stalls. |
| 73° | ,, | ,, | Boxes. |
| 74° | ,, | ,, | Gallery. |

The above results show the satisfactory manner in which the mode of ventilation that has been described effects the objects intended; but the full benefit of these results is unfortunately not received in the present case, from the arrangements being only partially carried into regular use; and it has to be remarked that however perfect the ventilating arrangements may be in the construction of a building, it is indispensable that the working of them should be under the constant charge of properly qualified and responsible management, in order to ensure the desired object being systematically attained.

(Dr Percy's acceptance)

# A SYSTEM

OF

# VENTILATION,

INVENTED AND PATENTED BY

## WILLIAM POTTS.

APPLICABLE TO ALL

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&c., &c.

LONDON:
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# PREFACE.

The object of the present pamphlet is to give an explanation of the phenomena connected with Ventilation, an outline of the efforts which have been made to obtain pure air in places where human beings and domestic animals have to exist, and to append a description of a simple invention by which this great problem is solved, and the circulation of the atmosphere preserved without draughts, in all seasons of the year, no matter what the temperature of the room may be.

# VENTILATION,

BY A NEW SYSTEM.

---

Before entering on a description of my System of Ventilation, I shall venture to give a brief history and explanation of previous plans, in order to show that it is the end and completion of all the appliances which have been tried to admit pure air into enclosed spaces of every description, to distribute it everywhere, and eliminate the vitiated air without exposing the inmates to the danger of getting chills and colds.

It is a singular fact that whilst Architecture made such wonderful progress during many ages, and has left monuments of its grandeur in almost every country, Ventilation seems to have been almost entirely overlooked until, little more than a century back, it forced itself on the attention of mankind by plagues, pestilences, and fevers of every kind ; but at last, as if to show how every member of society, high and low, are linked inseparably together, the gaols, prisons and convict-ships became the eloquent preachers of health to the English nation. These places were so unhealthy, that most of those who had not become regular gaol-birds died or contracted such diseases as impaired their constitutions for life. Nor was this all ; no one could come near them without danger of infection.

It had long been known that the sweating sickness, which continued here for more than a century, had been generated in the ill-ventilated ships which brought the tatterdemalions into England who formed the army of Henry VII. It was also known that at what is called the Black Assize, which was held at Oxford

in 1577, although most of the prisoners escaped the epidemic, all other persons who where present died in forty-eight hours—the judge, the sheriff, and about three hundred others.

Howard, the philanthropist, was greatly shocked by the ravages made by the gaol-distemper, which, he says, was unknown in the prisons abroad; and Sir George Paul, of Gloucester, writing about the same time, and probably influenced by what Howard was doing, shows that many debtors who had been arrested for very trifling sums died in prison. In reference to another class of prisoners, he adds, "It frequently happens that a verdict of honourable acquittal is announced to a wretch expiring in the agonies of a pestilential disease." At Taunton, in 1730, some of the prisoners infected the Court with the malaria they had brought from their cells, so that the judge, the sheriff, a serjeant, and more than a hundred others died.

Again, at the Old Bailey in 1750, a noisome smell was preceived in court by many who were present, and within a week a number were seized with a malignant fever. The Lord Mayor, Sir Samuel Penant, two judges, a baron of the Exchequer, an alderman, an under-sheriff, a barrister, some of the jurymen, and forty of the spectators died.

About the same time also, Dr. Lynd, in his "Essay on the Health of Seamen," asserts that the fleet was infected from the gaols, and that the ships lately sent to America lost two thousand men in consequence. It thus became clear that something must be done to render the gaols more healthy; and hence the first efforts to ventilate them.

And did we not know how utterly the study of Nature had been neglected, it would appear singularly strange that such terrible lessons as these should have been needed to teach people the simple laws of health; but this ignorance was common to all, the medical faculty included.

The harvest of death was reaped for centuries because people were ignorant of the nature of the atmosphere in which they lived and had their being; they were if possible still more ignorant of respiration, the action of the air on the lungs, and the changes which it effects in the blood, which is the very life and foundation of the animal kingdom.

That a pure Atmosphere is of vital importance to all must be evident when we think that respiration is rapid, constant, incessant from the cradle to the grave: upon the quality of the air men and animals breathe depends the condition of their health; and if vitiated atmosphere is breathed, or air deficient in oxygen, the consequences are not only injurious, but often destructive of human life.

Having premised thus much as the basis for a proper, rational, and, if the term may be used, natural system of Ventilation, it was necessary to study not only the laws which regulate the distribution of the atmospheric currents, but also what had been done by others, and what success had been obtained by them.

The difficulties which beset early experimentalists in Ventilation were how to get pure air to the spot where it was required in quantities sufficient to maintain the equilibrium of the atmosphere, an elimination or discharge of the vitiated air, *and to conduct this purifying process on a self-regulating plan, without draught.*

It is not a little singular that the first systematic efforts towards ventilating buildings were not made for the preservation of human beings. Gaols, hospitals, factories, and private houses were in the miserable state we have indicated, and no one we are aware of ever thought of purifying them. In France, however, it was found that the silkworm did not thrive in ill-ventilated rooms; and hence efforts were made to ventilate the places in which they were bred. The great improvement which took place immediately in the health of the insects very soon led to the adoption

of the plan in places where crowded assemblies of human beings had to meet.

Space will not permit a description of the plans and inventions which followed that of Dr. Hales for forcing air to where it was required by bellows. We may, however, state that up to the present time all the attempts which had been made may be classed under three heads. 1. Ventilation by apertures in the ceiling or walls, which have been differently placed by experimentalists. 2. Ventilating by means of pumps, fans, and bellows, variously placed and constructed ; and 3. Ventilation by means of fires so placed as to keep up a constant flow of air through shafts or tubes. These plans have of course all had their advocates, but it is hardly too much to state that they have all, more or less, signally failed.

A word or two on the cause of these failures will show clearly that my Patented plan (for which a fourth place may be claimed) of Ventilating by means of the cornices of rooms, combines all the advantages which can be derived from any of the others, and supplies the benefit which they failed to produce.

Firstly then the apertures in walls and ceilings failed when two kinds of air, viz., hot and cold, passed through the *same* openings, because the rushing in of cold air stopped the exit of vitiated air and drove it back injuriously into the room ; and where cold air was let into the *lower* part of a room, it rushed to the openings above, thereby creating draughts. The plans for ventilating by pumps, fans, or bellows have all been unsatisfactory, from their requiring machinery with special arrangements and superintendence, and also from their costliness.

The objections I have stated to apertures are equally applicable to the method of ventilating by fires. Create strong air-currents by any means, and you at once endanger the health of all who come near them.

The *upper* part of the room is the proper place for

the admission of fresh air. By this means the cold air enters at a distance from the occupants, becomes warm in descending, and produces no draught when admitted by a strip of gauze at the back of the lowest part of the cornice.

Although the upper part of rooms, and the cornice have been employed by others for ventilation, my system differs from all previous ones in *the use of two distinct passages in the cornice, one for the escape of the hot, the other for the admission of the fresh air.*

The nearest approach to my plan in its main features, though it was quite unknown to me till my invention was complete, was that discovered by a celebrated German physician, Dr. Bachrich, who saw the importance of separating the two kinds of air; and this he effected by placing two canvas bags in atmospheric connection with each bed in the fever wards of a hospital. They communicated with an inlet and an outlet at the upper part of the room, and respectively held pure and vitiated air. Of course such a plan would be very obstructive and objectionable anywhere, but totally inapplicable in ordinary rooms. My plan of making the cornice of rooms the entire seat of the ventilating process is unobjectionable in appearance, and does not interfere with other arrangements; and in fact introduces no change in the aspect of a room.

For forming my Patent Cornice, I have had recourse to metal (by preference Zinc or Tin) from its possessing many advantages over any other substance. Metal is easily moulded into any form, may be painted, gilt, or decorated in any way; it can be washed, cleansed, and renovated. The plan for fixing these metal cornices will allow of their being taken down at any time, and the mode offers advantages which will be easily seen and appreciated. Besides, metal cornices are cheaper than the ordinary plaster cornices, and a greater variety of brilliant effects can be produced in them than has been before attained; but plaster can be used if preferred.

By dividing the cornice about the middle, longitudinally, we have complete and separate air-chambers for the two kinds of air we have to deal with. That which has to be taken from the atmosphere without, by occupying the lowest chamber in the cornice, *forms a fount in every room of pure air, which will enter through the gauze without draught,* in the proportion required by the rarefaction in the air of the lower part of the room. It will thus be seen that the plan is self-regulating ; natural laws are made use of for supplying the purifying means, while the course of the denser cold air down the line of the walls will expedite the discharge of the lighter and vitiated air, which will, by its tendency to ascend, pass out of the room through the ornamental perforations in the highest members of the cornice into the chimney or any other flue. Thus a continuous circulation and change of air will be kept up without any excrescence, indeed, by beautifying the room, and all the advantages be gained which Dr. Bachrich procured for his hospitals, without his unsightly appliances.

The valves at the entrance and exit passages are by cords completely controlable, instantly either opened or closed, and the admission of cold air can be regulated to the nicest requirement.

As for health the ventilation of bedrooms is really of great importance, I recommend for the admission of pure air *two valves* in each room, one for the admission of cold air from without, which can be closed in the evening, or when desired, by merely drawing a cord fixed to a pulley on the wall and acting on the valve door, and then obtaining the desired change of air by opening the valve *communicating with the hall, which should have sufficient valves in it to make it a great reservoir for containing the desired quantity of pure air.*

The valve at the exit-passage to the hot-air flue should be left open as a general rule, but it can be

closed instantly if gusts come downwards, *though the arrangement by which the perforations in the cornice are closed on each side beyond the valve will prevent in all cases any unpleasant effects.*

Experiments show that though the Ventilating Cornice secures the *freshness* peculiar to the external air, the temperature is not lowered as compared with that of unventilated rooms under the same circumstances.

If any proof were needed of the advantage resulting from the constant egress of vitiated air, we have only to visit a badly-ventilated church or public room the day after it has been occupied by a large audience, when we shall find that the walls are still giving out the faint, sickly, disagreeable gases which they absorbed when previously occupied; and although a writer in the *Builder* may have rather overstated the case in asserting that the congregation of a badly-ventilated church frequently breathe the heavy atmosphere left by that of the previous Sunday, still there is an important fact at the bottom of the observation—the foul air long hangs about the building and poisons all who come into contact with it. This is why infected ships and houses have to be scrubbed, cleansed, and fumigated before they become safe places of abode.

After this general survey of the subject of Ventilation, at the risk of a little repetition, I may be pardoned for enumerating the special advantages which belong to this system; they may be stated thus:—

The air is taken from the highest attainable point. This is a matter of the greatest importance, especially in large towns, where all kinds of impurities abound, which are ever generating volumes of miasma; and the air can be thoroughly filtered before it enters the room by covering the air-entrances to the valves in the walls with a plate of metallic gauze, which will exclude blacks and other impurities. When it is

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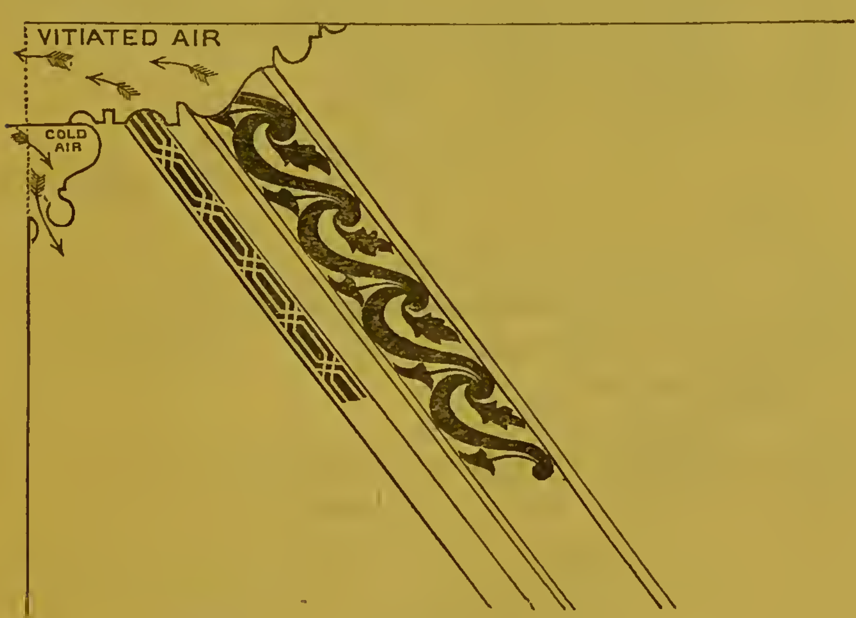

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BIRMINGHAM:
WHITE AND PIKE, PRINTERS, COMMERCIAL BUILDINGS.

# A SYSTEM

OF

# VENTILATION,

INVENTED AND PATENTED BY

## WILLIAM POTTS.

APPLICABLE TO ALL

DWELLING-HOUSES, PUBLIC BUILDINGS, HOSPITALS, MANUFACTORIES, RETAIL SHOPS, SHIPS,

&c., &c.

LONDON:
SIMPKIN, MARSHALL, AND CO.,
BIRMINGHAM: HOWELL AND DAY.
1868.

*PRICE SIXPENCE*

# PREFACE.

The object of the present pamphlet is to give an explanation of the phenomena connected with Ventilation, an outline of the efforts which have been made to obtain pure air in places where human beings and domestic animals have to exist, and to append a description of a simple invention by which this great problem is solved, and the circulation of the atmosphere preserved without draughts, in all seasons of the year, no matter what the temperature of the room may be.

# VENTILATION,

### BY A NEW SYSTEM.

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Before entering on a description of my System of Ventilation, I shall venture to give a brief history and explanation of previous plans, in order to show that it is the end and completion of all the appliances which have been tried to admit pure air into enclosed spaces of every description, to distribute it everywhere, and eliminate the vitiated air without exposing the inmates to the danger of getting chills and colds.

It is a singular fact that whilst Architecture made such wonderful progress during many ages, and has left monuments of its grandeur in almost every country, Ventilation seems to have been almost entirely overlooked until, little more than a century back, it forced itself on the attention of mankind by plagues, pestilences, and fevers of every kind ; but at last, as if to show how every member of society, high and low, are linked inseparably together, the gaols, prisons and convict-ships became the eloquent preachers of health to the English nation. These places were so unhealthy, that most of those who had not become regular gaol-birds died or contracted such diseases as impaired their constitutions for life. Nor was this all ; no one could come near them without danger of infection.

It had long been known that the sweating sickness, which continued here for more than a century, had been generated in the ill-ventilated ships which brought the tatterdemalions into England who formed the army of Henry VII. It was also known that at what is called the Black Assize, which was held at Oxford

of the plan in places where crowded assemblies of human beings had to meet.

Space will not permit a description of the plans and inventions which followed that of Dr. Hales for forcing air to where it was required by bellows. We may, however, state that up to the present time all the attempts which had been made may be classed under three heads. 1. Ventilation by apertures in the ceiling or walls, which have been differently placed by experimentalists. 2. Ventilating by means of pumps, fans, and bellows, variously placed and constructed ; and 3. Ventilation by means of fires so placed as to keep up a constant flow of air through shafts or tubes. These plans have of course all had their advocates, but it is hardly too much to state that they have all, more or less, signally failed.

A word or two on the cause of these failures will show clearly that my Patented plan (for which a fourth place may be claimed) of Ventilating by means of the cornices of rooms, combines all the advantages which can be derived from any of the others, and supplies the benefit which they failed to produce.

Firstly then the apertures in walls and ceilings failed when two kinds of air, viz., hot and cold, passed through the *same* openings, because the rushing in of cold air stopped the exit of vitiated air and drove it back injuriously into the room ; and where cold air was let into the *lower* part of a room, it rushed to the openings above, thereby creating draughts. The plans for ventilating by pumps, fans, or bellows have all been unsatisfactory, from their requiring machinery with special arrangements and superintendence, and also from their costliness.

The objections I have stated to apertures are equally applicable to the method of ventilating by fires. Create strong air-currents by any means, and you at once endanger the health of all who come near them.

The *upper* part of the room is the proper place for

the admission of fresh air. By this means the cold air enters at a distance from the occupants, becomes warm in descending, and produces no draught when admitted by a strip of gauze at the back of the lowest part of the cornice.

Although the upper part of rooms, and the cornice have been employed by others for ventilation, my system differs from all previous ones in *the use of two distinct passages in the cornice, one for the escape of the hot, the other for the admission of the fresh air.*

The nearest approach to my plan in its main features, though it was quite unknown to me till my invention was complete, was that discovered by a celebrated German physician, Dr. Bachrich, who saw the importance of separating the two kinds of air; and this he effected by placing two canvas bags in atmospheric connection with each bed in the fever wards of a hospital. They communicated with an inlet and an outlet at the upper part of the room, and respectively held pure and vitiated air. Of course such a plan would be very obstructive and objectionable anywhere, but totally inapplicable in ordinary rooms. My plan of making the cornice of rooms the entire seat of the ventilating process is unobjectionable in appearance, and does not interfere with other arrangements; and in fact introduces no change in the aspect of a room.

For forming my Patent Cornice, I have had recourse to metal (by preference Zinc or Tin) from its possessing many advantages over any other substance. Metal is easily moulded into any form, may be painted, gilt, or decorated in any way; it can be washed, cleansed, and renovated. The plan for fixing these metal cornices will allow of their being taken down at any time, and the mode offers advantages which will be easily seen and appreciated. Besides, metal cornices are cheaper than the ordinary plaster cornices, and a greater variety of brilliant effects can be produced in them than has been before attained; but plaster can be used if preferred.

By dividing the cornice about the middle, longitudinally, we have complete and separate air-chambers for the two kinds of air we have to deal with. That which has to be taken from the atmosphere without, by occupying the lowest chamber in the cornice, *forms a fount in every room of pure air, which will enter through the gauze without draught,* in the proportion required by the rarefaction in the air of the lower part of the room. It will thus be seen that the plan is self-regulating ; natural laws are made use of for supplying the purifying means, while the course of the denser cold air down the line of the walls will expedite the discharge of the lighter and vitiated air, which will, by its tendency to ascend, pass out of the room through the ornamental perforations in the highest members of the cornice into the chimney or any other flue. Thus a continuous circulation and change of air will be kept up without any excrescence, indeed, by beautifying the room, and all the advantages be gained which Dr. Bachrich procured for his hospitals, without his unsightly appliances.

The valves at the entrance and exit passages are by cords completely controlable, instantly either opened or closed, and the admission of cold air can be regulated to the nicest requirement.

As for health the ventilation of bedrooms is really of great importance, I recommend for the admission of pure air *two valves* in each room, one for the admission of cold air from without, which can be closed in the evening, or when desired, by merely drawing a cord fixed to a pulley on the wall and acting on the valve door, and then obtaining the desired change of air by opening the valve *communicating with the hall, which should have sufficient valves in it to make it a great reservoir for containing the desired quantity of pure air.*

The valve at the exit-passage to the hot-air flue should be left open as a general rule, but it can be

closed instantly if gusts come downwards, *though the arrangement by which the perforations in the cornice are closed on each side beyond the valve will prevent in all cases any unpleasant effects.*

Experiments show that though the Ventilating Cornice secures the *freshness* peculiar to the external air, the temperature is not lowered as compared with that of unventilated rooms under the same circumstances.

If any proof were needed of the advantage resulting from the constant egress of vitiated air, we have only to visit a badly-ventilated church or public room the day after it has been occupied by a large audience, when we shall find that the walls are still giving out the faint, sickly, disagreeable gases which they absorbed when previously occupied ; and although a writer in the *Builder* may have rather overstated the case in asserting that the congregation of a badly-ventilated church frequently breathe the heavy atmosphere left by that of the previous Sunday, still there is an important fact at the bottom of the observation—the foul air long hangs about the building and poisons all who come into contact with it. This is why infected ships and houses have to be scrubbed, cleansed, and fumigated before they become safe places of abode.

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BIRMINGHAM:
WHITE AND PIKE, PRINTERS, COMMERCIAL BUILDINGS.

# IN THE SENATE OF THE UNITED STATES.

FEBRUARY 20, 1865.—Ordered to be printed.

Mr. BUCKALEW submitted the following

# REPORT.

*The Joint Select Committee of the two houses of Congress appointed at the last session to examine into the present condition of the Senate chamber and hall of the House of Representatives, as regards lighting, heating, and ventilation, and their acoustic properties, and the defects and disadvantages existing in the same, make the following report:*

That pursuant to the resolution of appointment they have obtained from Charles F. Anderson, architect, a statement of the principles upon which he proposes the improvement of the halls of Congress, as regards the particulars above mentioned, and also estimates of the expense that will attend the proposed alterations, and they append the said statement and estimates to this report. They have also obtained plans and drawings of the proposed changes of the halls and Capitol wings, as authorized by a clause of the miscellaneous appropriation act of 2d July, 1864, which are deposited with the Secretary of the Senate for examination by the members of both houses. The committee have also taken the voluntary testimony of a number of witnesses upon the several subjects covered by the present inquiry, to enable them to come to intelligent conclusions, and they now beg leave to submit that testimony in connexion with this report for the information of Congress.

The committee propose, in the first place, to examine the several defects alleged to exist in the present arrangements relating to the halls of Congress, and particularly those relating to their ventilation; next to state distinctly the character of the changes proposed; and, lastly, the time, manner, and cost of their accomplishment.

First, then, as to existing defects:

## PLACE OF OBTAINING AIR.

1. The air for ventilating the halls is now taken from the levels of the terraces, between the wings and the old Capitol building, on the western side. To these situations much dust and other impurities are carried by the action of winds, subjected to the influence of eddies, and taken with the air through the ventilating passages into the halls. And in warm weather the terraces and adjoining walls, becoming heated, affect very considerably the temperature of the air obtained. Reference upon this point of the inquiry is made to the testimony of Dr. Antisell, and Mr. Forney, the engineer in charge of the ventilation of the House of Representatives. It is manifest that the air introduced into the halls should be obtained from places not subject to the accumulation of impurities, or to the undue production of heat.

### OVERHEATING THE AIR.

2. By the examination of the engineer in charge of the heating and ventilating department of the Senate chamber, it appears that the air on its passage to the chamber is heated exclusively by steam, introduced into mazes of pipes for the purpose. Hot water is not used, and it seems certain that the air is overheated and thereby subjected to injurious changes. Professor Wyman says: "In all cases in which it may be necessary to warm the fresh air required to be supplied to an inhabited room or cell, it is essential to health that the increased temperature should be derived from a moderately heated surface; hence the advantage of using water as a medium of heating. In a hot-water apparatus of ordinary construction, the temperature of the surfaces when exposed to a current of air will never reach the boiling point, and it is obvious that they may be regulated in any lower degree that is likely to be useful."

Among the conditions prescribed for the warming apparatus of Pentonville prison—the "model prison"—was the following: "That the entire radiating surface should derive its temperature from the circulation of hot water, and that it should be of such an area as would maintain a temperature of 60° in the cells when the external atmosphere was at 32°; further, that under ordinary circumstances the temperature of the heating surface should not range above 100° to 120° of Fahrenheit."

This point of over-heating the air demands amendment which must be secured in any new arrangement regarding ventilation.

### DEFICIENT MOISTURE.

3. But one of the most manifest and material defects in the ventilation of the Capitol wings, is, the exceeding aridity of the air supplied. To this point the committee have given particular attention, and the information obtained upon it is most conclusive in condemnation of the existing arrangement. Both health and comfort are disregarded in forcing into the halls air containing but one-third, to one-half, the moisture or vapor of water required at the temperature to which it is raised. It is to be taken for granted that the natural constitution of air at any given temperature is better adapted to life and human comfort than an artificial one can be, and it is to be secured as nearly as possible in all structures designed for human occupancy. In a free atmosphere the demand for moisture caused by increased temperature is fully supplied from natural sources. But, in moving air through a confined space destitute of watery vapor, and subjecting it on its passage to the action of heat, while its character must undergo a change as to temperature and density, there will be no corresponding change in the amount or proportion of moisture it contains. In other words, moisture must be imparted to it by artificial means if its true natural constitution is to be maintained. That a principle so well known and so indisputable should have been ignored in the ventilation of the Capitol is most surprising, and indicates, if it does not prove, incompetency or indifference to duty in the superintendency of the building.

Doctor Reid observes, that "the moisture in the air is not to be regarded as an adventitious ingredient, but rather as an essential component of atmospheric air. It requires in general to be added to air in cold climates in winter in proportion to the temperature communicated to it before it approaches the person. If cold air be heated in spring and summer by natural causes, it absorbs a proportional share of moisture in general from the surface of moist ground, lakes, and rivers, or from the ocean, and thus reaches the system in a congenial condition. On the other hand, if cold and dry air be heated artificially without receiving moisture, its increased power of absorbing moisture renders it offensive to the system."—*Reid on Ventilation*, sec. 341, 43.

"The amount of evaporation into equal spaces is dependant upon the temperature, and increases considerably on a small increase of heat." Between 32° and 100° the amount of evaporation is doubled by the addition of about 20°, or at 52° it is double that of 32.° * * * In winter, the air, when extremely cold, is proportionably free from moisture. The true time, acordingly, when moisture ought to be applied to air is not when it is warm in spring and summer, but as it is warmed artifically in winter. The temperature and moisture of the air are certainly the most important circumstances that demand attention after securing air of sufficient purity. (*Ib.*, *s.* 350, 436, 511.)

Professor Wyman says that "air holds in solution a variable amount of aqueous vapor, limited by the temperature. The influence of this agent upon the human system is exceedingly important. The lungs are continually exhaling moisture, its quantity depending upon the hygrometric state of the atmosphere. If the air be too dry, the lining membrane of the lungs, throat, and mouth, may be deprived of necessary moisture so rapidly that an uncomfortable degree of dryness, or even inflammation, may be induced. Undoubtedly, the best constitution of the air is that which nature affords. During the summer months the air has gradually increased in temperature, aud appropriated from rivers and other sources that amount of vapor which is required. In our houses we should imitate the same course, and, heating air from below 32° to 70°, provide a sufficient supply of water." (*Wyman on Ventilation*, *pp.* 190, 91, 96.)

"Air changed in temperature by warming without increased moisture is apt to produce unpleasant feelings and painful sensations in the chest, which are often attributed to too great heat. In very dry air the insensible perspiration will be increased, &c. The objection lies against *heated* air, no matter how heated. Stoves and air furnaces with their red-hot surfaces are undoubtedly worse for the air than hot water apparatus which never scorch it, yet the latter may pour into our apartments a withering blast of air at 150°, which may be potent for mischief. The only way that hot air can be made healthful and desirable is by an effectual plan of artificial evaporation." (*Dr. Youmans' Handbook of Social Science*, 308.)

Appended to this report, is a paper furnished the committee by Dr. John A. Rowland, showing the capacity of air for moisture at different temperatures, both as to volume and weight, to which reference is made for further information upon the present point. The figures are obtained from works of reputation, and they show that the air of the halls during the winter and spring requires two or three times the amount of moisture actually contained in it; for its aridity, caused by heating it, is modified in no way whatever, not even by leakage of doors and windows, as in the case of an ordinary apartment.

But what determines the condition of the air in this respect with perfect certainty is the examination given it by Dr. Wetherill of the Smithsonian Institution. He examined the air of the Senate chamber on the 24th of January, and on February 9th, and states the results in his testimony. Indicating the saturation point of air at any given temperature by the number 100, we have a standard established for comparison, when ascertaining the quantity of moisture actually present in any specimen of air. Upon ascertaining the amount so present, it may be indicated by a number which will bear the same relation to 100 that the amount found present bears to the amount which would be present if the air were completely saturated or contained moisture to the full extent of its capacity. And in such case, the number indicating the quantity present is called the "relative humidity" of the air examined.

Now the mean annual relative humidity of atmospheric air in England has been ascertained to be about 75°, saturation being, as before stated, 100°. Mr. Roscoe states that in the house of lords the air is pleasant to breath when its relative humidity ranges between 55° and 82°. But Dr. Wetherill found the relative humidity of the air in our Senate chamber on January 24th to be as fol-

lows: In ladies' gallery, near reporters' gallery, at 2¼ p. m, 27. In same, near diplomatic gallery, 27. On same day, at 3 p. m., the relative humidity of the external air entering the ventilating fan, was 56.

On February 9th, with a relative humidity of external air at 55 at 2½ p. m., he obtained the following results in the Senate chamber: in southeast corner of chamber on a level with desks, at 3½ p. m., relative humidity, 20; in diplomatic gallery, at 4 o'clock, 21.

These astonishing but indisputable results prove that upon that occasion less than one-third the proper amount of moisture was present in the air of the chamber.

An observation taken by him at 4.30 p. m. of the same day in the air-space above the ceiling is also instructive. He found the temperature to be 64°, while the temperature in the hall below at the previous observation had been 70.9° upon the floor, and 68° in the diplomatic gallery. An enormous influence of the roof in producing cold, and affecting the air of the halls, is shown by these figures. It was a cold day, with an external temperature of 30.6°.

It may be added, that by observations taken at the Smithsonian Institution for the months of February and June, 1859, there being three observations daily, the mean relative humidity of the atmosphere for the former month was 71, and for the latter month, 69. Therefore, on the 9th of February, 1865, the air used in ventilating the Senate chamber, with an external February temperature, and an inside temperature of June, had a point of relative humidity in the chamber that required to be multiplied by 3½ to raise it to the proper Washington average.

With good reason, therefore, does Dr. Antisell declare in his testimony that one of the capital defects of our ventilation is the want of hydration of the air of the halls.

Some attempt has been made to hydrate the air recently, but in a very insufficient manner, and without material effect. The laudable effort of the present sergeant-at-arms of the Senate, with insufficient space and facilities at command, to hydrate the air of the Senate chamber, deserves commendation.

But to accomplish the object in view a radical change in existing general arrangements is required. Dr. Reid states that, in ventilating the English House of Commons when it was crowded, he often exposed the air furnished to 5,000 feet of evaporating surface to impart the necessary moisture, *and subsequently made the air flow through jets of water.* (*Youmans*, s. 347.)

The ideas that have obtained in the ventilation of the capitol may be estimated by the statement made to the committee by the present architect, that he proposed to hydrate the air of each hall by passing it over an evaporating surface of forty square feet. The committee are not prepared to recommend this particular experiment. (A subsequent statement was, thirty feet of heated water, or a surface a little exceeding four feet by seven.)

"When dry air is exposed to a source of moisture, a considerable *time* must elapse before it will become saturated. The diffusion of vapor into hot air is much more rapid than into that which is colder, but it is not at all instantaneous. Mr. Daniell observed that a few cubic inches of dry air continued to expand by the absorption of humidity for an hour or two, when exposed to water of the temperature of the surrounding air."

It follows, that the dry and warmed air for supplying rooms of great magnitude must be passed over an evaporating surface of great extent, in case that mode of hydrating it be adopted. Doubtless, warming the water would increase the efficiency of the plan. Dr. Antisell recommends spray or jets of water thrown into the air at a right angle to its current, which would no doubt be an effective and satisfactory mode of accomplishing the object where the necessary facilities can be established, among which space is indispensable. The objections to the use of steam, on an extensive scale, for hydration, are, the production of

noise, and, as alleged, of odor, and its imperfect dissolution in the air before entering the chamber. It passes on with the current of air for some time before it becomes dissolved and incorporated with it, and moisture is deposited upon all surfaces with which the volume of air comes in contact. There is no arrangement for introducing steam into the air passing to the halls, but it was provided for the air directed to the committee rooms and passages. The plan was not found to work well, and has not been in practice.

DUST RISING IN THE HALLS.

4. Dust rising in the halls from the floors. This defect arises from the introduction of air through horizontal openings in the floors, and is an inconvenience which should be abated, if possible.

In Dr. Reid's arrangements for ventilating the former House of Commons, mats and Russian scrapers were provided in the lobbies to secure the greatest possible exclusion of every source of impurity from the floor; the air being admitted through the floor by numerous apertures.

This difficulty of dust rising in the room, as well as the introduction of refuse substances into the horizontal openings in the floor, would be mitigated, though not entirely removed by the introduction of the air through the risers of the steps behind the seats of members. That was the original plan, but it was abandoned, as was also the free introduction of air into the sides of the room, because of the unpleasant currents produced. No doubt the latter effect would be decreased, if not removed, by proper hydration of the air; for it is quite certain that a current of dry air, although at a high temperature, will produce chilliness, on account of the rapid evaporation caused by it.

INEQUALITY OF TEMPERATURE.

5. Unequal temperature in the halls at the same level. The statements of temperature which appear in the evidence establish and illustrate this point; the temperatures given of the hall of the House are average ones; observations of a number of thermometers, at the same level in various parts of the hall, differing several degrees from each other, being taken. The Senate chamber temperatures are those of single instruments with their particular locations noted, differing, in some cases, five degrees or more from each other at the same level, but on opposite sides of the chamber. The certain result of these differences of temperature is to cause unequal movement of the air and to disturb the regularity of the ventilation. The air will ascend unequally in different parts of the halls, and perhaps, also, some disturbance of sound will be thereby produced.

EXTREME HEAT.

6. Extreme degree of heat in the halls. The thermometrical observations, beside showing differences of temperature, show also an excessive degree of heat. The average exceeds 70°, whereas it should not exceed 65° to 68°.

"In private houses the air should never be allowed to remain above 70° when warmed by heated air; when heated air is used in connexion with open fires, or other radiating bodies, the temperature will not often require to be above 65°." (*Wyman*, p. 188.)

"The best temperature for a room is 65° to 68°. (*Youmans*, s. 21.)

*Temperature in former House of Commons.* "The house is heated to 62° before it is opened, and maintained generally at a temperature varying between 63° and 70°, according to the velocity of the air passing through the house." (*Reid*, s. 659.)

A proper temperature is fixed by Dr. Antisell, in his testimony, at 66°. In

fact, a temperature exceeding 70° in the halls would be intolerable were it not for the aridity of the air; because of *that*, rapid evaporation takes place, rendering individuals less sensitive to the presence of heat. But the degree of heat to which individuals are subjected in the halls is probably injurious, and is in more marked contrast to the external temperature than is desirable. These observations relate to the winter and spring months, but the temperature of the halls in summer is often offensively high during both day and night sessions; for the heat passing through the roof into the halls by day, and the heat thrown down by the lights at night, are equally intrusive and objectionable. There was no necessity for establishing the conditions from which these effects follow; and the heat, which sometimes reaches nearly 90° in the halls, is productive of much discomfort, is injurious to health and obstructive of legislation. In summer the air is sufficiently moist, but temperature is less subject to regulation than in winter.

### COMMUNICATION WITH AIR SPACE ABOVE THE CEILING.

7. The air of the halls is not kept distinct and apart from the air of the spaces above the ceilings. It is, therefore, subject to the influence of the roofs and of the lights. From this cause the ventilation of the halls is disturbed, and rendered imperfect, as will be shown under subsequent heads.

### THE ROOFS.

8. The roofs are exceedingly objectionable as they exist at present, composed in part of metal and in part of glass, generating cold or admitting heat according to season, and conducting the noise of storms enormously and offensively to the halls. In erecting them, it seems to have been forgotten that this Capitol was not to be an Egyptian or Grecian temple, under a genial sky, nor even a Roman church, in the mild climate of Italy, but a great structure for the use of legislative bodies, in a comparatively inclement location upon the banks of the Potomac. Windows upon the sides, for lighting the halls, if made double, would not only have accomplished their office more perfectly than a glass roof, but would have protected the air of the chamber from all injurious influence of the external atmosphere, and from the intrusion of all external sound; and even the entrance of solar heat, now enormous, and incapable of regulation by the roof, might have been excluded, by shading, when necessary, the windows exposed to it. Light from side windows would be soft, natural, cheerful, and diffused, producing perfect illumination of the whole interior space, including the galleries, now so unequally and imperfectly lighted. And, finally, windows, unlike the roof, might be thrown open at pleasure, and thus, at proper seasons and upon fit occasions, rapid and thorough ventilation of the halls secuced.

### THE LIGHTS.

9. The particular arrangement for lighting the halls by gas jets above the ceiling is another defect requiring attention. The jets are very numerous—those used for lighting the hall of the House exceeding twelve hundred in number. The amount of heat created by them is very great, and the quantity thrown down into one of the halls at a night session increases the temperature of the hall from three to five degrees. This is peculiarly disadvantageous in summer, and renders night sessions uncomfortable, there being no effective arrangement for cooling the hall. There is an unnecessary consumption of gas, and the products of combustion are not effectually removed.

Dr. Reid says: "When any vitiated air is produced by a gas lamp or other artificial light, or by any manufacturing operation, too much importance cannot be attached to the desirableness of involving it directly in a stream or current of air by which it is conveyed to a channel where it cannot possibly contaminate the air of respiration." (S. 458.)

It is to be remembered that there is extensive communication between the hall and the air space above the ceiling, where the lights are placed, through numerous apertures along the ceiling, allowing impurities of combustion to pass into the halls with any downward current. And Dr. Antisell explains, that the accumulation of hot air under the roof without sufficient means of exit is to back up against the out-going currents from the hall and prevent their escape.

There can be no doubt that comparatively few lights arranged with reflectors and ventilating chimneys, would light the halls perfectly, would throw down but little heat into them, and would thoroughly ventilate the air spaces above the ceiling, assuming that they were cut off (as they should be) from any communication with the halls.

### IMPERFECT REMOVAL OF AIR.

10. One principal defect of ventilation is, the imperfect removal above of the vitiated air of the halls. Under this head two points are to be considered: 1st. That the avenues of escape for the air are inadequate, and, 2d, that no exhausting power is applied. Whatever of escape takes place is simply from the natural ascent of heated air, and this action is insufficient and irregular from defective arrangements. In the case of the Senate hall the apertures for the escape of the air have a deficient capacity of one-sixth as compared with the entrance shaft, or passage below. The velocity of escape is deficient also to the extent of one-third as compared with the entrance movement produced by the fan. Great irregularity and imperfect ventilation are the necessary results.

As to the application of artificial power for the removal of the air, Dr. Antisell says: "The chief power should be placed at the point where the air is thrown out or removed from the building. I look upon a fan for the introduction of air as of secondary importance compared with a fan placed at a point where the air is removed. The object is to remove the air that has become impure, and it may be done much easier and with more certainty if the power is applied at the removing point."

Question. "Do you consider the application of power for the removal of air from a chamber more important than for its introduction?

Answer. "Certainly; that is the main point. The main power should be applied where the air is to be removed, and for this reason: You are never sure, in driving air in, that it arrives at the point desired; but if you take it out of the room the thing is palpable."

Now, at present, the air is forced by fans into the halls and then allowed to take its own course, subject, however, to all the disturbing causes which exist in the halls or above them. No power is applied to produce certainty and regularity in its removal.

### CARBONIC ACID GAS.

The presence of carbonic acid gas in the halls is, no doubt, in excess of the quantity contained in the external atmosphere, but the committee have not been able to obtain any exact determination regarding the quantity present, either at ordinary sessions or upon extraordinary occasions. The detection of this gas, and an exact determination of the amount of it contained in air, require skill, careful attention, and instruments and materials of analysis of much perfection. Of atmospheric air in a state of ordinary purity, carbonic acid gas constitutes but about four parts in ten thousand, and even in air overcharged and rendered unhealthy by its presence, the quantity contained is exceedingly small. But the examination upon this point now being prosecuted by Dr. Charles M. Wetherill, of the Smithsonian Institution, will furnish information approaching exactness, as his capacity and fidelity are both unquestionable. In the absence of reliable information, no clear opinion can be formed upon this subject, but

the committee are induced to think that the contamination of the air of the hall from this cause, is not very excessive or injurious. The reasons for this opinion are, the great size of the halls, the fact that notwithstanding defective movement of the air in ventilation, the quantity of air removed within a given time must be very considerable, and that the halls are usually occupied but a few hours at one time. Upon extraordinary occasions, when the galleries are well filled, it is probable that defective ventilation permits an unhealthy accumulation of this pernicious gas, and its enormous production by the lights, without perfect exclusion from the halls, may produce contamination of the air, even below the ceiling.

Such, then, are the existing defects to which the attention of the committee has been directed, and they may be briefly summed up as follows:

That the air is taken from an improper place, where it contains dust and is over-heated in summer. That it is over heated by steam pipes. That the air as introduced into the halls during the winter and spring months of the year does not contain more than one-third to one-half the moisture or vapor of water required at the temperature to which it is raised. That its aridity is a capital defect, and demands radical change and amendment. That dust rises in the halls from the introduction of the air through the floors. That temperatures are unequal in the halls at the same level.

That the heat is extreme in the halls, at least by 5° or 6°, and most excessive in summer, both by day and night, from the influence of the roofs and lights.

That the air of the halls is not kept distinct and separated from that between the ceilings and roofs.

That the roofs are very objectionable both from their construction and the materials of which they are composed, and that for the glass roofs, side windows, made double, would be an admirable substitute.

That the present arrangement for lighting the halls is bad.

That the removal of the air from the halls is imperfectly accomplished, the outlets being inadequate, and no exhausting power provided.

### THE PLAN OF IMPROVEMENT.

The changes and improvements proposed by Mr. Anderson, the architect, are stated in detail in his report to the committee, which is appended hereto, and are shown and illustrated by his plans and drawings which accompany it. He proposes to obtain air from situations upon the bank west of the building, through vertical shafts of some elevation; to conduct it through protected passages into the sub-basement, and then conduct it upwards through appropriate passages to air chambers outside and near the upper part of the halls. From these distributing chambers it is to pass through ducts over the ceilings, and obtain admission to the chambers through the present apertures in the ceilings. The entire movement of air so far is to be produced and regulated by a powerful fan placed near the bottom of the ascending passage, and provision is made for warming the air upon its way by hot-water pipes, and for cooling it in summer by the use of ice. He proposes also to place jets of water in the outer entrance shafts, and to provide most ample and effectual arrangements for hydrating the air before it reaches the ceiling. The space at command will enable this to be done perfectly, thus removing wholly one of the main defects in the existing arrangement. The removal or exhaustion of the air from the halls will be through the floors and through the present passages used for the introduction of air, powerful fans being again used for accomplishing this purpose.

### THE PLAN CAN BE REVERSED.

Now, whatever opinion may be formed of the merits of the plan thus far, as to the movement of air in the process of ventilation, it is manifest that it pos-

sesses the merit of being capable of exact reversal. At any time, if desired, the air may be introduced from below, conveyed upward through the halls, and exhausted through the proposed entrance-passages of the place; in which case it would become, as to its general features, almost the identical plan successfully adopted by Dr. Reid for the ventilation of the former House of Commons. In fact, such reversed plan would have a material advantage over the Reid arrangement in the use of an effective exhausting-fan instead of a fire and chimney. Dr. Antisell and Mr. Cluskey correctly state that such reversal of the plan, as to direction of the movement of the air, could be made with little expense and alteration if desired hereafter. This consideration meets any possible objection to the downward movement of air through the halls, by those who may not be convinced of its utility, efficiency, and success.

### ELEVATION OF CEILINGS AND ROOFS.

But a most material part of the proposed plan—that which involves most of expenditure and requires most of careful investigation—is the elevation of the ceilings and roofs, with the accompanying and consequent changes.

It is proposed to elevate the ceiling and roof, in each wing, about fifteen feet; to make the roof double, the inner one counter-ceiled with non-conducting material; to substitute a limited number of lights, with reflectors and ventilating chimneys, for the present numerous gas jets, and to insert windows around the whole upper part of the hall in the space gained by the elevation of the ceiling and roof. Thus, the air-space above the ceiling, separated entirely from the ducts through which the air for the hall is introduced or exhausted, will be ventilated by the chimneys of the lights; all the products of combustion will be at once removed; abundant light, with little heat, will be produced; all influence of external heat or cold and all noise from storms will be prevented by the double roof and the insulated air space above the ceiling, and perfect illumination of the hall and galleries, with other advatages, secured by the side-windows introduced. There can be no doubt that these would be most valuable improvements upon the points involved in this inquiry, to wit: the heating, ventilation, and acoustics of the halls of Congress.

The laws of architectural proportion require the elevation of the ceilings, and the appearance of the halls (and particularly the hall of the House of Representatives) would be greatly improved thereby.

The original plan of Mr. Anderson, which was mainly followed in the construction of the halls, and in their location in the centre of the wings, contemplated windows above, as now proposed, and it is not likely that any competent architect would ever propose such rooms, so located, without any possible access to solar light except through the roofs.

Besides, it is insisted upon by professional gentlemen, and appears to be true, that the architectural effect of the Capitol, viewed externally, would be improved by the moderate elevations proposed to be added upon the wings. The sky line of the structure would be somewhat broken, which would comport with the style of Roman art upon which the Capitol was originally designed—the Roman-Corinthian order—and the attention now fixed, concentrated, and absorbed by the great central dome, would take in the whole structure and recognize the wings in which the great legislative houses, composing the Congress of the United States, are assembled.

The elevations would recede inwards some distance from the outer vertical line of the wings, and none of the present or proposed exterior work upon the wings would be disturbed.

## OBSERVATIONS UPON THE PLAN.

Recurring to the details of the plan of changes already stated, the committee have some additional observations to submit upon particular points.

It is questioned by a most competent witness examined by the committee, whether entrance shafts for the external air so high as twenty-five or thirty feet, are necessary or expedient, and also whether jets of water in those shafts would be an advantage. The committee conclude that neither point is very important, and, however determined, will not materially affect the general plan; a proper place for obtaining the air being the main object to be secured in the first instance. As to passing the air over ice in the summer, for the purpose of cooling it, the committee think that the use of cold water in the pipes used in winter for warming the air would usually be sufficient for a proper reduction of temperature. In hydrating the air the use of an extensive system of jets or spray of water, reasonably warmed, in the ample space at command by the plan, would be the most efficient and satisfactory. Any use of steam must be in moderate quantity, and at some considerable distance from the point of entrance into the chamber, to permit its perfect absorption and dissolution in the air. Level evaporating surfaces would require to be of great extent; their arrangement might impede the movement of the air in ascending, and might cause accumulation of dirt or impurity. The plan of hydration here suggested is contained in the testimony of the intelligent and able witness already mentioned, and is concurred in by the architect. Another suggestion from the same source, as to an easy improvement of the openings of the ceilings for the passage of air, is believed to be judicious. The windows to be introduced into the upper part of the halls should unquestionably be double, and, in the opinion of the committee, no stained glass should be used in their construction.

## THE DOWNWARD MOVEMENT OF AIR.

But one additional feature of the plan remains to be considered—the proposed downward movement of the air through the halls. In his "Notes upon Acoustics and Ventilation," submitted by Captain M. C. Meigs to Jefferson Davis, Secretary of War, May 19, 1853, the advantages of the descending movements are stated to be, the avoidance of all eddies, a nearly homogeneous and tranquil atmosphere, and the immediate removal downwards of any dust from the carpet which would thus be prevented from rising to be inhaled into the lungs; and it is insisted upon that good acoustic results would be secured. The plan of Captain Meigs for the ventilation of the halls of Congress was undoubtedly derived from Mr. Anderson, whose plans, with printed explanations, were in his possession for some time, and obviously adopted and followed to a great extent in the construction of the wings. The "Notes on Acoustics and Ventilation," elaborating the advantages of the descending movement, are therefore appended to this report, and in connexion therewith the emphatic indorsement of them as correct and judicious by Professors A. D. Bache, of the Coast Survey, and Joseph Henry, of the Smithsonian Institution. The views thus presented and indorsed were the views of Mr. Anderson, and are exactly applicable to the plan now proposed by him, and they retain whatever of soundness and force they possessed in 1853, notwithstanding they were subsequently departed from in the construction and arrangements of the halls.

But there are two material advantages of the descending movement of air which were not stated in the "Notes" referred to, to wit: the equalization of temperature in the halls, and particularly near the floors, and the economy or saving of heat; both which are important and evident. They are stated by Dr. Antisell, and to be taken into consideration in determining the plan now

under consideration. For the differences of temperature upon opposite sides of the hall, constituting one of the existing defects, would be wholly avoided by the downward movement. The tendency of the air after its admission at the ceiling, and during its progress to the floor, would be toward equalization and uniformity of temperature, and the *movement* also would be comparatively regular until acted upon very near the floor by outgoing currents. The argument, therefore, for improved acoustics by the downward movement, as given in the "Notes," is strengthened by these considerations. The facility of heating the hall, and economy in the use of heat for that purpose, would also be greatly increased. For a considerable time is now required for warming one of the halls, inasmuch as the heated air when first introduced passes rapidly to the ceiling and roof, the colder air remaining in, or falling to, the lower parts of the hall. The process must therefore be continued until the entire space is thoroughly warmed, and if the air is introduced at a proper temperature several hours will be required for this purpose. Besides, a great amount of warm air is wasted in heating the space between the ceiling and roof, and a large amount necessarily lost by the roof itself, as before mentioned. But in introducing the air above, as proposed, with an exhausting power below, the room can be warmed rapidly, the exhausting fan withdrawing the cold air with certainty and despatch and permitting its place to be occupied by the descending volume of warm air No heat will be lost by the roofs, nor diverted to the air spaces between them and the ceiling.

The "Notes" correctly state, that "by a steam-driven fan, or other mechanical means, we can pump air, in any desired quantity, into any spot to which we choose to direct it."

The fan is now the accepted instrument for the movement of air by either the plenum or vacuum impulse, where great efficiency is desired, and its improvement has been carried so far as to leave little to be desired. Where the size of a building warrants its use, it gives any desired power with certainty and cheapness, and is capable of adjustment in almost any position where the limited space required by it can be obtained. And it has superiority over a chimney with fire, in its capacity to move air in *any* direction, and to move it regularly and with greater efficiency. Placed as a power to supply or exhaust a room, its force can be exactly calculated and the result intended precisely accomplished. The exhaustion of the air of a room by it in a downward direction can be made at pleasure. It is simply a question of the application of a power entirely at command, in an intelligent manner.

A few notable instances of downward movement in ventilation may be mentioned, and first that of the model Pentonville Prison of which Professor Wyman says: "The arrangements which have been in operation ventilating and warming the cells, and maintaining an equable, general temperature within the prison, have been attended with complete success." The air is introduced through horizontal passages warmed by hot-water pipes, and passing upward along flues, is admitted into each cell at the top immediately under the ceiling. It is withdrawn from the cell on the opposite side, at the floor, and passing upward through flues is eventually discharged by a high shaft above, into which the smoke-flues from the heating apparatus also enter. "It will thus be seen that a communication is established, first, from the outer air through the warming apparatus to the top of each cell, and thence from the floor of each cell through the extracting flues and ventilating shaft into the outer air again."

"A perfect diffusion of air takes place in the cell, the difference of temperature at the ceiling and floor can scarcely be detected, and will seldom exceed one degree, and it may be inferred that the difference of power required for extracting the air at one or the other of those levels would be inappreciable."—*Wyman.*

Of course, if the air were required to pass down from the cells to the basement, some appropriate power would be necessary to accomplish the movement.

The ventilating movement of air, as above described, is assisted in the winter by the smoke and disposable heat in the shaft above, from the heating apparatus, and in summer a small fire, maintained at the bottom of the shaft, is used. In short, the assisting power used is very slight, and yet it is said by an intelligent author, that "so admirably is the ventilation of the building contrived and kept up that there is not the least sense of closeness pervading it; for we feel immediately we set foot in the place, how fresh and pure is the atmosphere there."—(*Mayhew's Prisons of London*, p. 120.)

A diagram of the fine Portland prison, showing the introduction of air into the compartments, both above and below, on one side, and its exhaustion on the opposite side at the floor, is to be found in the Prison Commissioners' Report, volume 29, for the year 1850.

In the case of the New York Hospital, upon Broadway, designed by Mr. Anderson, and where the plan of ventilation is successful, the air is obtained through shafts of neat appearance about twelve feet high, placed outside the building, is carried into a passage of the sub-basement, from thence admitted to the heating apparatus above, there warmed by hot-water pipes, and permitted to ascend and enter the wards upon the sides. It is removed upon the opposite side, through openings into flues above and below, either of which may be used, but those at the floor are found most efficient in practice and remove all offensive odors of wounds and sickness from the room. The exhausting flues are connected with a small room above, in which hot-water pipes are placed to assist the movement and discharge of vitiated air. The statement of the engineer in charge is attached to this report, and confirms the opinion of a member of the committee who visited the building, that the air of the wards is good, and the whole arrangement of ventilation judicious. The use of a fan would increase efficiency of movement, if that should be desired, in this or any other building of like arrangement.

In the case of the new emigrant hospital now in course of erection on Ward's island, New York, the air is obtained through an elevated shaft placed some distance from the building, and conducted through brick ducts, and then upward through iron shafts, through openings in which it is admitted into the different wards. It is removed through openings near the floors, behind the patients' beds, and discharged into the atmosphere in the usual manner. The letter of the architect, describing the plan, is hereto attached.

## OBJECTIONS CONSIDERED.

Professor Wyman states very clearly the objections to the downward movement of air which have prevented its general adoption in buildings with much force and clearness; but it will be observed that they have no application to the plan now under consideration. The first is, that this movement requires that the openings for the escape of the air should be nearly as numerous and diffused as those for its admission in the ceiling, and for most evident reasons. Ordinarily, however, such numerous apertures at the floor cannot be secured; but in our case they already exist, and the objection fails. Another objection in ordinary cases is, that in the downward movement the lights must be provided with air entirely separate from that which supplies the room, in order that the gases and other products of combustion shall not be breathed. But in the present plan the separation of the space where the lights are placed from all communication with the air of the hall is one of its main features, and easily secured. We may add, that the perforation of the ceiling for the diffused admission of the air is often inconvenient or impossible, and that facilities for op-

erating an exhausting power below, do not exist. None of the ordinary difficulties opposed to the descending movement are, therefore, to be encountered in the present case. Its practicability however, is admitted by our author in strong language, and its desirability indicated where the conditions exist for its application. He says: "The flow of air may, when under the control of an efficient moving power, take any direction that may be desired; it may move from below upwards, or the reverse, or in both directions at the same time. * * * There is no impossibility of producing a constant and equable downward movement. * * * The unoccupied ceiling, in its whole extent, may be used for the admission of air which may reach the lungs uncontaminated by dust or contact with the body. This is the movement which constantly arises in rooms heated by means of fire-places, &c."

He explains that heated air first rises to the ceiling and afterwards, upon cooling descends and is removed by the chimney.

It is a common practice in ventilation upon the removal of ascending air at the top of the room, to take it down a side passage and deliver it into the external atmosphere. This may be accomplished by a fire-place at the bottom of the passage, connected with an upright shaft or chimney, as in the case of the temporary House of Commons, or much better, both as to efficiency and regularity, by an exhausting-fan. But manifestly this downward exhaustion of air accomplished in the side passage may be accomplished equally well in the room itself as to air introduced at the ceiling.

Only one point remains to be noticed under this head—the ascent of impurities from the bodies of persons occupying a room. Evaporation from the skin and air breathed from the lungs convey impurity to the air, and cause an ascending movement in the first instance, and it is said that from this cause the descending air may be contaminated before it reaches the person. It is true that air breathed from the lungs is usually warmer than the air of the room, and has an ascending force mainly due to the elesticity of its watery vapor. But its superior temperature is quickly lost, and, in accordance with the well-known law of diffusion of gases, it becomes incorporated with the descending air, and passes downward. As some time is necessary to contaminate the air, it follows that in a descending movement all impurity is removed below the region of respiration before it becomes appreciable or injurious; and as the whole air of the room is changed within a period of less than ten minutes, there can be no such accumulation of impurities in any particular section of air as to render it offensive or objectionable. The floors of the galleries being perforated with numerous openings for ventilation, no vitiated air produced there will pass down to the floor of the hall.

The committee have given this elaborate examination to the subject of ventilation by a downward movement of air, not because its approval is indispensable to the plan proposed by the architect, but because it is desirable to adopt a plan which will allow the application of that particular arrangement. The plan will stand good for an upward movement of air through the halls, but, for the reasons already given, sustained by the authorities cited, the downward movement appears to promise the most complete and satisfactory results in ventilating the halls of Congress.

## RÉSUMÈ.

In summing up the whole case upon the architect's plan, it may be stated to involve the elevation of the ceiling, the insertion of side windows, the removal of the glass roof and substitution of a double roof, the separation of the air-space above the ceiling from all communication with the hall, the substitution of fewer lights with reflectors and ventilating chimneys for the present lights, the introduction of pure air from an external point by a fan, with proper warming and

thorough hydration, and its effectual and regular removal from the hall by an exhausting fan; and, by the plan, either an upward or downward movement of air through the hall may be established; a change from one movement to the other requiring only a change of location in the heating and hydrating apparatus. Upon the merits of the plan reference is made to the testimony of Mr. Cluskey and the other witnesses, and particularly to the following question and answer in the examination of Doctor Antisell:

"Question. What do you say as to the feasibility and success of Mr. Anderson's whole plan as compared with the present arrangement?

"Answer. It would be much more effective than the present plan, and feasible in its details."

The evidence of the same witness upon the utility and advantages of an exhausting fan in ventilation is also worthy of particular notice.

THE ESTIMATES.

The concluding subject for examination under the resolution appointing the committee is the cost of the proposed changes. The careful and elaborate estimates laid before the committee, and herewith reported, show a total expenditure for the Senate wing of $113,185 25, independent of an attic for the erection of which the estimate is $37,500. For the House wing the expenditure is $15,921 30 more. The erection of an attic upon it would cost the same as for the Senate wing, being of the same size. These estimates are made at the present prices for labor and materials, and as to nearly the whole proposed outlay assume the form of proposals by a competent party. Underwritten his estimates for the wings, respectively, (including nearly the whole of the work and materials,) Benjamin Severson, the directing engineer in erecting the present ceilings and roofs, proposes to execute a contract at the prices stated, and to give ample security for its performance.

If the plan of improvement now submitted to the two houses be regarded with favor, the committee recommend that the improvements of the Senate wing be executed between the termination of the present and the commencement of the next session of Congress. There will be ample time for this purpose, and an advantage in concentrating attention and effort upon the one wing. In proceeding, subsequently, to the improvement of the House wing, the temporary roof, fixtures, and implements used in the work upon the Senate wing can be transferred to the other; and any improvement or modification of details in the general plan can be applied in executing the work upon the House wing.

The expenditure for the Senate wing, exclusive of the attic, will fully secure all the changes and improvements proposed in the plan examined by the committee; in other words, will secure the elevation of the ceiling and roof, with side windows and all the arrangements of ventilation. Attics, however, will properly follow the other proposed changes, and are required for architectural effect. Marble, already on hand, can be made available in their construction.

With this question of expenditure upon the proposed improvements, a collateral one, relating to the wings, may be considered. The present plans of the Capitol extensions indicate expensive colonnades upon the north, south, and west sides of the building, to be placed upon the arcades already erected, and an appropriation of $300,000, applicable to their construction, was made at the last session. That appropriation remains unexpended, and the question arises, whether it would not be well to withhold it from the volume of public outlay. There is no necessity for the present expenditure of this large sum, and the utility and advantage of making it, at any time, is matter of debate. Mr. Anderson, in his testimony, says:

"I recommend that you finish these arcades with cornice and balustrade at

the top, which will produce a good architectural effect by carrying out the principles of a Roman structure more fully than to finish them as heretofore proposed. It is not intended to put porticos but colonnades over the arcades. The plan is, to carry round the entablature on those colonnades. The effect of it would be simply this: A column before each pilaster has no object of any kind effected by it. It involves an additional expense of marble-work and excessive weight, without any possible advantage. Standing at right angles with the building these columns would not be seen more than the pilasters would which stand by them; they would merely obscure the pilasters, and at the same time deprive the numerous offices on each side of the building of air and light. It is an object in architecture never to introduce an ornament without a purpose. In every well-designed architectural building there never is an ornament introduced that has not its object, which this feature of the design of the Capitol has not. The same observation is applicable to all of the four colonnades—north, south, and two west." * * * "A balustrade would be a great deal cheaper than the other plan, and it would, at the same time, admit more air and light." These views seem to be forcible and just, and are, therefore, brought to the attention of Congress for consideration.

Upon due reflection, the committee are induced to submit the question of withdrawing the appropriation for the colonnades, or at least deferring the expenditure, in view of an inquiry through an appropriate committee as to their utility and merit. If balustrades can be substituted for them without disadvantage, a very large amount of money can be saved to the treasury, and the burden of the expenditure now proposed by the committee for real and necessary improvements in the Capitol wings be mainly avoided.

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## ARCHITECT'S REPORT.

*To the honorable the Joint Select Committee of the Senate and House of Representatives of the United States, on the subject of lighting, heating, ventilating, and the acoustics of the two halls of Congress.*

The report of Charles Frederick Anderson, architect and civil engineer, of the city of Washington, D. C., most respectfully represents—

That in obedience to your appointment and directions, made in pursuance of the concurrent resolution of the two houses of Congress of the 10th of May last, the undersigned has diligently applied himself to a minute examination of the various parts of the north and south extensions, and to the various plans and drawings of their several parts which will necessarily have to be used or which will be slightly affected by the plan by which he proposes to improve the lighting, heating, ventilating, and acoustics of the halls of Congress, with a view to discover the most direct, easy, and economical manner in which the plan can be applied to the structure as it now exists.

This examination has the more strongly and clearly developed the errors of those parties having charge of the construction of these extensions, in departing from the plans which the undersigned had the honor to furnish for the accomplishment of these objects, and which had been submitted to President Fillmore, and been supported by Mr. Webster, then Secretary of State. During the administration of President Pierce these same plans were submitted to him, and fully examined and approved by Montgomery C. Meigs, then captain of United States engineers and superintendent of the Capitol extension, and by Professors Bache and Henry, and were also approved by the Secretary of

War, under whose direction the works had been placed, as will fully appear by the documents appended to this report; and yet, strange as it may appear, Captain Meigs, in his actual construction of the extensions, not only rejected this plan for the lighting, ventilating, and heating of the legislative halls, but actually reversed the whole system, making the error radical, and therefore more difficult now to remedy or correct. However, by a thorough study and examination of all the parts, the undersigned flatters himself that he has (by his accompanying plans) established the means of making the desired improvements with the least possible alteration or change in the interior arrangements; none, in fact, which will occupy any material apartments or space of the extensions, or injure or interfere with the present appearance and arrangement of the halls of Congress in any way, except to lighten up and greatly improve their interior appearance, as well as the exterior superstructure; all of which will be shown and explained by this report, and by the drawings and plans herewith submitted.

The erroneous plan adopted by Captain Meigs, which has been operating since the occupation of the halls, and now exists in both houses, receives the exterior air under the ground floor from off the surface of the overheated and dusty terraces, furnishing much of the bad air from beneath, carried to its surface by evaporation and side currents of air from the ground, and this air is also tainted with much of the odors caused by the machinery near which it passes.

The air injured by these causes is drawn to the openings in the cellar or sub-basement walls by the action of the fan-wheel, which forces it up under the floors of the two houses, where it finds vent through the gratings under the members' desks, the risers in the floors, and openings round the halls, and in the galleries. By the action of these currents the vapors introduced from below rise from the floors of the halls, and keep in constant motion the vitiated air generated by the breath of the persons occupying the floors and the galleries, of which carbonic acid gas, being heavier than the purer part of the atmosphere of the chambers, is constantly tending to and settling upon the floors, and would remain upon the floors, like a malaria or noxious miasm, were it not kept in motion near the floor by the currents of dirty air coming up through the gratings and registers; there is added to this bad air all the dust produced by the walking or movements upon the floor, independent of that brought from below. This atmosphere of the halls, as at present arranged, cannot be otherwise than unwholesome, and, were it not for the frequent opening of the doors leading into the halls, would prove much more oppressive and intolerable than it is. To persons of weak lungs, however, the deleterious effects of the present arrangement are more immediate and sooner felt than by persons blessed with more robust constitutions; but even these may be taken sick without any apparent cause, unless it can be traced to the fact that the seeds of the sickness have been unconsciously imbibed while sitting quietly in their seats, and much more so while engaged in speaking, or in the heat of debate, when the lungs must of necessity become inflated and irritated by this pernicious atmosphere.

From these remarks it will be manifest to the plainest understanding that a great error has been committed in attempting to furnish the proper air to the halls, passing it through and mixing it up with the vitiated air as above explained, instead of introducing the pure air into the upper elevation of the halls, and drawing down the impure atmosphere through the gratings in the floor. Having thus simply explained the errors of the present system, it is the purpose of the undersigned to explain the principles and the manner in which he proposes to remedy the existing errors and defects, and furnish to the national councils a pure, temperate, and refreshing atmosphere, of an equal temperature at all seasons, in which members may with safety exercise their lungs while conducting the high and important legislation of the country, with ease and pleasure, and without any apprehension of receiving injury from the medium

through which their views, arguments, and business transactions may be expressed in the two Houses.

To accomplish this purpose, the undersigned will endeavor to be as succinct as the nature and the importance of the case will admit of, and, with this view, will divide his explanations as follows, viz:

1st. The undersigned proposes to furnish an abundant supply of fresh, unadulterated air, rarified in winter, hydrated, purified, and cooled down to any desired temperature in summer, to the halls of Congress, so as to insure a uniform temperature at all seasons, with a healthy atmosphere, to be effected by vertical air shafts to be built on the banks on the west side of the Capitol extension, one for each wing, twenty-five feet high over the level of the flagged terrace, and in the position marked on the accompanying plans of the sub-basement floors, *(specified by the red tint;)* through these shafts pure air, procured from that elevation, will pass into the air chambers on the sub-basement floors, through dry tunnels, seven feet six inches in diameter, built of hard brick and cement twelve inches thick, and cemented on the inside, so as to make them impervious to damp, with a fall to the vertical shaft, in which shaft a jet of pure water will play at discretion, and be capable of adjustment in the engine-room.

In the sub-basement air chambers are iron stands on which to pile ice in hot weather, and through which the hydrated and purified air will have to pass to the fan-wheel, which will force it upwards through the building to the upper air chamber arranged outside of the chamber walls, and from which it will pass into the halls of Congress through close air-tight ducts, made of two thicknesses of thin galvanized sheet iron four inches apart, filled in between with crushed pumice stone and liquid cement, passing through the perforations in the ceiling as through a sieve—this perforated portion of the ceiling forming the under side of these air ducts.

The large upper air chambers outside of the halls will be arched over with brick and cement, so as to render them impervious to the influence of the exterior atmosphere, either hot or cold, and the air ducts on the ceiling, which are fed directly from these large air chambers, are packed on three sides with non-conducting material, as before described, so as to transmit this purified, cooled, (or rarified,) air to the halls without being sullied by its passage through the atmosphere over the glass ceiling.

The undersigned has arranged four new fan-wheels to carry out his plan, two to force the air up and two to withdraw the vitiated atmosphere from the floors; one for each house. These are so formed as to possess five times the power of the present fan-wheel, but the power is completely under the control of adjustment. The flow of air into the halls may be as required, and will be regulated by the speed of the fan-wheel, which depends on the action of the engine.

When very cool air is required in excessive hot weather we can lower the temperature of the exterior atmosphere to any extent desired, in the halls of Congress, by placing ice in the vertical shaft as well as in the lower air chambers, and still further by the use of salt with the ice.

All this air passes from the vertical air shafts through the tunnel, which will be built into and covered up from the effects of the atmosphere by the present bank of earth extending to the basement air chambers, and from thence up through the building to the upper air chambers which supply the air ducts over the ceiling; will be made close, clean, and pure, with a drain built at the bottom leading to the vertical shaft from the lower chamber and the ice cellar, to take off the water introduced by the jet, the melting of the ice, or the rain water in the vertical shafts.

The undersigned has also annexed the adjoining cellars in each wing (now useless) for stores or ice houses, where a supply can be kept convenient to the lower air chambers for daily use when required. In cold weather steam ad-

mitted through the cluster of pipes now in use, but placed in the new air passage, will rarify the air to any temperature required on its passage to the upper air chamber, through which chamber a stream of pure water will be made to flow, so as to hydrate the heated air before it enters the halls. This can be accomplished by allowing the stream of either warm or cold water (to suit the temperature of the air) to flow over a continuous tray the full length of the upper air chamber, fitted with a gauze wire bottom and divided into compartments, so as to be able to adjust the amount of mist through which the ascending air will pass at right angles. The temperature of this air, subsequently, will receive additional protection at certain seasons by the admission of air through a register from the upper air chamber to the space over the glass ceiling, and the influence of the exterior atmosphere will be kept off the glass ceiling by means of a counter ceiling placed on the back of the iron rafters which support the roof and the ceiling, which rafters it will be necessary to strengthen to double their present capacity. This counter ceiling will be composed of crushed or broken pumice stone, filled in with liquid cement, resting on thin corrugated galvanized sheet iron; it will be five inches thick, packed close, made air-tight, and plastered on top with cement. This counter ceiling will prove to be a non-conductor of heat, cold, or sound from the exterior copper covering of the roof, leaving a space of three feet between the exterior covering and this counter ceiling.

This plan will effectually prevent the changes in the weather, either by heat, cold, or storms, from affecting the glass ceiling as it does at present, and which has been so much complained of; in fact, the temperature of these halls could never be properly regulated so long as the exterior atmosphere could control the temperature of the space over the glass ceiling, which is at present assimilated to a hot-house in summer and an ice-house in winter, besides transmitting noise from the effects of hail and rain storms, so annoying to the members of both houses of Congress. It will be only fair to all parties that it should be known that this system of lighting the halls of Congress by means of skylights is the only part of Mr. Walter's two designs which have been brought into operation by Captain, now General, Meigs, and which injudicious act is a principal cause of the heated ceilings and bad acoustics.

The undersigned proposes, as an extra or auxiliary means of heating the halls of Congress, in very cold weather, to place ornamental benches in the angles of the halls and in the hat-rooms, filled with coils of steam pipes, to supply additional heat on the floor of each house, which will obviate the necessity for heating the upper current of air too highly to be pleasant.

2d. The undersigned proposes to withdraw the vitiated air from the chambers without its remaining above the floors to become injurious to the occupants, and at the same time to regulate and insure good acoustics to both halls of Congress.

To accomplish these objects the present system will have to be completely reversed by using the same apertures for withdrawing the vitiated air from the halls of both houses and from the galleries that is at present used for admitting the air into these apartments, being the registers on the floors, in the galleries, and in the screens which enclose the halls, &c., &c.

This will be accomplished by means of powerful fan-wheels, made to work in the passages which at present admit the air, and in as close proximity as possible to the openings under the floor, through which these fan-wheels will withdraw the vitiated air. The power of these exhausting fan-wheels upon this air can always be regulated to a certainty by their velocity, which will be controlled by the action of the engine.

The current of fresh air passing through the halls downwardly will also be regulated in a great measure by the action of these exhausting wheels, which will regulate the acoustics, as will be made evident from the fact that the voice can no longer ascend to the roof and be lost in the space over the ceiling, as at

present. The compressed air forced through the perforations in the ceiling, as through a sieve, will oblige the voice to remain in the body of each house; it being an axiom in the science of acoustics that glass, next to water, possesses the greatest attraction for sound. The attraction of the voice produced by the glass-paneled ceiling over both the halls of Congress, as at present, will be obviated altogether by the introduction of the imperceptible flow of pure air into each house from the ceiling. As sound always accompanies the current of air, it will be decoyed from the glass ceiling, and conveyed into the body of the chambers and into the galleries, as above described, without a reverberation of the voice produced by the present low glass ceiling. The proposed elevation of the glass ceiling, besides improving the architectural proportions of the chambers, will materially assist in establishing good acoustics, as the large field of attraction for the voice will be further removed from the floor, besides being intercepted or arrested on its passage to the ceiling by the incoming flow of pure air through the many apertures in the ceiling, and a greater space will be afforded for the action of that incoming current to mix with the air in the chambers before it reaches the floors. The undersigned recommends that the system heretofore specified in the printed explanations which he furnished to Captain Meigs in 1853, be now adopted for conveying and dispersing the superabundance of sound on the floors to the galleries, and to the reporters' desk in particular, by inserting open slits in the surrounding screen, to which will be attached zinc tubes, which will arrest the voice and convey its redundancy from off the floor to the galleries. It will be perceived that by this system the voice cannot escape from the halls in consequence of this plan for admitting the pure air, and by means of these tubes the vibration of the voice or echo will be altogether done away with, so that the full effect of the voice will be rendered more agreeable by this wholesome atmosphere, produced by purified and compressed air. It will be seen, by the accompanying plans, that this change can be effected without interfering with the arrangements on the floors or galleries in either house, or the surrounding corridors, passages, or offices, in any way save by the occupation of one or either of several spaces, the selection of which may well be left to the honorable Committee on the Public Buildings, or any other authority deemed most appropriate, to select a passage for the pure air from the basement to the upper air chamber, which can be spared with the least inconvenience, that is, if the passage laid down on the plans for the Senate wing be not approved of. With this exception, it will be perceived by the drawings that this plan for securing good ventilation, &c., interferes with nothing in the halls that can be visible under the level of the cornice of the present ceiling which surrounds the halls of Congress; everything below that level will remain as at present arranged. According to this plan there will be two objects attained: first, to establish what is required by the concurrent resolution; and, second, that it may be effected with as few changes and at as small an expenditure of time and money as is possible; such a change, however, in the present halls of Congress might be considered cheap at any cost, as it will insure the health of the nation's representatives.

3d. This plan will furnish a good and agreeable direct light by day from windows opening on the exterior atmosphere, with a steady, clear gas-light by night, descending through the present glass-paneled ceiling, as elevated, but without the accompanying heat produced by the great number of gas-burners at present distributed all over the ceilings of the two halls of Congress, numbering about one thousand four hundred over the ceiling of the House of Representatives alone, the effect from which renders the heat of the glass and iron ceiling particularly oppressive.

To remedy the present defects, it is proposed to raise the ceilings over the two halls of Congress about sixteen feet, which will produce much better proportioned apartments, as the height of the present ceilings is altogether at va-

riance with architectural rule, or the laws which govern architectural proportions. This change, beside improving the architectural appearance of the halls, will afford room to insert a tier of windows extending all around each hall under the cornice and over the gallery doors, as shown by the accompanying longitudinal and cross sections. These windows will be the exact size of the windows in the committee rooms on the basement floors; a direct light will be admitted through the upper half of these side windows, twenty-six in number in the House, and twenty-two in the Senate, as well as a borrowed light through seven of the end windows in the Senate chamber, and through nine of the end windows in the House of Representatives. The upper half of the sashes will open on pivots, and when open will admit the air through the halls from the exterior atmosphere, but which will never be required in consequence of a sufficient supply of better air being at all seasons within command by means of the above arrangement; besides, open windows would of necessity damage the acoustics. These windows would be hid from exterior view by the erection of the high parapet, (called an attic in architecture,) on which will be placed the present balustraded battlement, and which is recommended in Senator Foot's report as necessary to relieve the present bad effect of the upper monotonous straight line of the whole building, which is at variance with Roman architecture, (the style of the Capitol building.) The increased elevation of the wings is further called for in consequence of the enormous size of the new dome, (copied from the dome of St. Paul's in London,) the new dome of the Capitol being fully one-third larger than it should be if constructed in accordance with the rules which govern the order of Roman architecture to which the Capitol building belongs. A dome is a prominent ornament to a classic structure, but always subordinate to the proportions and style of the building; but in our case the building is made subordinate to the dome. The published remarks of an educated northern tourist are particularly applicable, when he terms it, "The great dome, with the low buildings beneath, which form the Capitol of the United States." The base of this new dome is actually made to project beyond the front walls of the building, and rest on the projecting portico which forms the principal entrance to the rotundo. To elevate the wings will in some measure disguise this architectural blunder.

Thus it will be perceived that by this one plan two great objects will be effected—better light will be given and better proportions to the halls, and at the same time it will materially improve the exterior architectural appearance of the building. (See accompanying sections and elevations.)

The new windows will be filled in with stained glass, which will produce a soft and agreeable light.

It is proposed to light the Senate chamber at night by means of eight circular burners of Frink's patent, with powerful reflectors, one placed over each; and the House of Representatives with thirteen circular burners, having a reflector over each, by which means the light can be increased to any amount desired, and the present objectionable heat from the great number of unprotected burners on the ceiling will be altogether done away with, as there will be placed over each reflector a copper dome, surmounted by a copper chimney eight inches in diameter, passing out vertically through the roof, which must attract all the heat upwards, while it reflects all the light downwards. To elucidate which the undersigned submits the accompanying drawings of Frink's patent reflectors, which he would recommend as the best means of lighting the halls of Congress.

The air which this plan introduces through a register from the upper air chamber into the open space between the glass ceiling and the new counter ceiling will increase the draft upwards from the burners under these reflectors and over the glass ceiling, through the flues over the reflectors, which will remove the possibility of communicating any heat from the burners to the glass

ceiling, while the counter ceiling will protect the glass ceiling from the influence of heat or cold from the exterior atmosphere.

The undersigned begs leave to submit a drawing of Reigart's improved fan-wheel, by which he proposes to supply and control the pure air to be furnished to the halls, and to draw the vitiated air therefrom.

He also begs leave to submit specifications and detailed estimates for the construction of the different works more fully described by the plans for the alterations, which he has the honor to submit in obedience to the instructions of the honorable joint committee.

To remove all apprehension upon the subject, the undersigned would respectfully state that these plans will not interfere with the present condition or appearance of either of the halls below the level of the present glass ceiling, while the arrangements above will establish better architectural proportions, symmetry, and beauty to these halls—a desideratum which he trusts it will not be considered out of place for him to say would have been effected in the original construction of the north and south extensions of the Capitol had his plans been fully and fairly carried out.

Desiring to confine this report to a plain and simple statement of what has been required of him by the joint resolution and the directions of the joint committee, the undersigned has omitted to introduce any reference to the authorities sustaining the principles of the plans which he has the honor to propose; but to aid the judgment and strengthen the opinions of this honorable committee and those of the honorable members of the two Houses, who are so deeply interested in the subject-matter under consideration, he would beg leave to append notes, communications, and reports of high authorities, thereby removing the idea of any presumption on his part of presenting a plan whose principles had not been fully approved by science and practical experience, and which approval the undersigned made himself fully aware of before he submitted his first design, in answer to the published invitation to the architects of the United States, in the year 1850, by practically investigating the different systems for ventilating public builings in Europe, in particular the Bank of England, the United Service Club House in London, the new British Houses of Parliament, the Millbank Penitentiary, and the Pentonville Model Prison. He investigated the system of ventilation adopted in the two last-mentioned establishments under an order from the Home Secretary, Sir James Graham—which order will be found recorded in the visitors' book during the summer of 1845—a copy of which could be had upon application in London, which would at once prove his practical experience of this system which he has throughout advocated. Under these circumstances, the undersigned can with confidence assure the honorable committee that there can be no possible doubt as to the result, and it will be possible to successfully carry out the necessary alterations during the interval between the end of the present Congress and the regular annual meeting of the next Congress.

For the more minute and particular explanation of his plan, the undersigned begs leave to submit the following drawings, viz:

*Senate Wing.*

No. 1.—Plan of sub-basement floor, showing the alterations.
No. 2.—Plan of basement floor, showing the alterations.
No. 3.—Plan of the principal and upper floors, showing the alterations.
No. 4.—Longitudinal section of wing, showing the alterations.
No. 5.—Crosss section of wing, showing the additions.
No. 6—Section showing the vertical air passage.
No. 7.—Plan of air ducts over the ceiling.
No. 8.—Front elevation of north wing, showing the attic.

No. 9.—Drawing of Reigart's improved fan-wheel.
No. 10.—Drawings of Frink's patent reflector.

*House of Representatives.*

No. 11.—Plan of sub-basement floors, showing the alterations.
No. 12.—Plan of basement floor, showing the alterations.
No. 13.—Plan of principal and gallery floors, showing the alterations.
Fo. 14.—Longitudinal section, showing the additions.
No. 15.—Cross section, showing the alterations in roof.
No. 16.—Section showing the vertical air passage.
No. 17.—Plan of the air ducts over the ceiling.
No. 18.—Elevation of the south wing, showing the additions.
No. 19.—Estimate, &c., from competent parties.

Alll of which is most respectfully submitted by

CHAS. FRED. ANDERSON,
*Architect and Civil Engineer, Washington, D. C.*

*December* 5, 1864.

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## REPORT OF CAPTAIN MEIGS.

OFFICE OF THE EXTENSION OF U. S. CAPITOL,
*Washington, May* 19, 1853.

DEAR SIR: Having verbally, in my interview with the President and yourself, fully explained the proposed changes, with the aid of large drawings, showing the accommodation to be afforded, it is not necessary here to enter into detail. [*These were the drawings furnished by C. F. Anderson.*]

I will only repeat my own conviction, that the proposed change will secure a better room for speaking, and hearing, and better accommodations for the members and officers, and business of the House.

I have prepared some notes upon the application of the general principles of acoustics and ventilation, which have guided me in devising the plan which I propose.

They contain the views I expressed to you verbally, and which I propose to write out for submission to some gentlemen of eminent scientific reputation.

While I feel confident that I am correct, I shall be happy to be sustained by their approval if right, and will be much better satisfied to be corrected if wrong, than to be permitted to go on and fail in so important an undertaking.

The changes which I recommend in the plan of the south wing, in order to carry out the above views, are shown upon drawings which have already been explained to you.

I would like to have an opportunity to show them to the gentlemen to whom you will refer these notes.

To lay down general principles correctly is not sufficient security that the application of them will be judiciously made.

I am, sir, very respectfully, your obedient servant,

M. C. MEIGS,
*Captain of Engineers in charge of Capitol Extension.*

Hon. JEFFERSON DAVIS,
*Secretary of War.*

*Extracts from "Notes on Acoustics and Ventilation with reference to the new Halls of Congress," by Captain Meigs, United States Corps of Engineers; May*, 1853.

Experience shows that the human voice, under favorable circumstances, is capable of filling a larger space than was ever probably enclosed within the walls of a single room.

If sound be prevented from spreading, and losing itself in the air, either by pipe or an extensive flat surface, as a wall or still water, it may be conveyed to a greater distance.

A pure atmosphere being favorable to the speaker's health and strength, will give him greater power of voice and more endurance: thus indirectly improving the hearing by strengthening the source of sound, and also by enabling the hearer to give his attention for a longer period unfatigued.

The common mode of warming and ventilating public rooms is fatal to perfection of hearing.

One or several columns of intensely heated air are introduced through holes in the floor. Being much warmer than the air of the apartment, they immediately rise to the ceiling. If the exit apertures for foul air are above, this fresh and heated air above escapes, having done nothing for the apartment except to cause whirls and currents, such as we see in a column of smoke passing from a chimney on a calm day. The irregular refraction of sound through these currents of equal density tends greatly to produce confusion.

If the exits for foul air are below, the hot air accumulates at the top of the room, and, gradually displacing the cooler air, forces it out through the passages.

Professor Reid relates that he has found the air near the ceiling of a room at the boiling temperature while those on the floor were complaining of cold.

Here we have a strata of different densities and unequal refractive power, and hence confusion of sound.

As the warmer air must ascend to the top of the room, I propose to let it do so in a large trunk outside of the apartment, pass into a space above the ceiling, and thence, by numerous holes, find its way, as through a sieve, into the room.

By a steam driven fan, or other mechanical means, we can pump air, in any desired quantity, into any spot into which we choose to direct it.

I would drive all the air required for the supply of the room through a maze of hot-water pipes, raising the whole of it to the temperature desired—60° or 80°, as the case might be.

If the room be thirty feet in height, and it be desired to change all the air in it every fifteen minutes, enough air should be pumped in above to cause a general descent of the whole body of air in the room, at the rate of two feet a minute.

This would be an imperceptible current. The exit should be by numerous holes in the floor, perhaps through the carpet, or the risers of the platforms on which are the members' chairs.

Three important advantages would thus be gained: The avoidance of all eddies, a nearly homogeneous and tranquil atmosphere, and the immediate removal downwards of any dust from the carpet, which would thus be prevented from rising, to be inhaled into the lungs.

To prevent the disturbance and contamination of the atmosphere by the gas-lights, I would place them above the glass of the skylights—the space between those in the ceiling and those in the roof being separated from the chamber into which the fresh air should be admitted.

In summer, the same apparatus which sends in warm air in winter would supply a constant breeze; and, if the temperature of the external air was too high, it might be cooled by jets of water from pipes in the passages, or even by melting ice.

I feel confident that, by observing the above prescribed precautions, we will obtain rooms as near perfection as is possible—" rooms in which no vitiated air shall injure the health of the legislators, and in which the voice from each member's desk shall be easily made audible in all parts of the room." [*This was Mr. Anderson's plan.*]

This was the problem proposed to me for solution.

In conclusion, I have the honor to repeat the request made verbally some days since, that the above notes and observations may be submitted to some persons of scientific reputation, the weight of whose authority may sustain me if I am right, or correct them if wrong.

Respectfully submitted to the honorable Jefferson Davis, Secretary of War, by his obedient servant,

M. C. MEIGS,
*Captain of Engineers, in charge of Extension of United States Capitol and Washington Aqueduct.*

Subsequently, the subject having been referred to Professors Bache and Henry, those gentlemen addressed a communication to the Secretary of War as follows:

SIR: The undersigned have examined, as you requested, the principles proposed by Captain M. C. Meigs, of the Corps of Engineers, with reference to the acoustics, heating, and ventilation of the hall of Representatives.

They are now prepared to report that the principles presented to them by Captain Meigs are correct, and that they are judiciously applied.

They are of opinion that the plans should be provisionally adopted, in order that the building may not be delayed, subject to such modifications in the details as may result from the further study of them by Captain Meigs, or from the experiments and observations of the commission.

This general adaptation of the plans will not, it is believed, interfere with any changes of details likely to be found desirable.

Very respectfully, yours,

A. D. BACHE.
JOSEPH HENRY.

Hon. JEFFERSON DAVIS,
*Secretary of War.*

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ESTIMATES.

*Senate Chamber—abstract estimate.*

| | |
|---|---|
| Altering roof and raising ceiling, &c | $27,979 20 |
| Scaffolding and machinery for all work | 10,000 00 |
| Brick work in raising the chamber walls | 11,929 05 |
| Air ducts over the ceiling, two thicknesses | 5,593 00 |
| New windows round Senate chamber | 3,600 00 |
| Belt course under the windows | 784 00 |
| Gutters and eve cornice | 3,700 00 |
| Remodelling flank roof and gutters | 5,000 00 |
| Workmanship on attic walls and balustrade | 37,500 00 |
| Mason's work in alterations air-shaft and tunnel | 20,000 00 |
| New steam engine | 2,000 00 |
| Two new fan-wheels | 3,000 00 |

| | |
|---|---|
| Eight reflectors, fixing and pipes | $9,600 00 |
| Rearranging, rarefying steam pipes, &c | 5,000 00 |
| Lining upper air-chamber so as to make it water-proof, with hot and cold water pipes and sieve the entire length | 5,000 00 |
| | 150,685 25 |

The above calculations are made at the present prices for labor and materials.

CHARLES F. ANDERSON,
*Architect and Civil Engineer.*

*Hall of Representatives—abstract estimate.*

| | |
|---|---|
| Altering roof and raising the ceiling, &c., &c | $38,970 10 |
| Raising the brick walls round the hall | 13,925 45 |
| New windows round the hall | 4,400 00 |
| New belt course under windows | 928 00 |
| Air ducts over ceiling, two thicknesses | 6,783 00 |
| Gutters and eave cornice | 4,500 00 |
| Remodelling flank roof and gutters | 6,000 00 |
| Workmanship on attic wall and balustrade | 37,500 00 |
| Alterations in mason's work, air-shaft and tunnel | 15,000 00 |
| A new steam engine | 2,000 00 |
| Two new powerful fan-wheels | 3,000 00 |
| Thirteen reflectors, including fitting and pipes, &c | 15,600 00 |
| Rearranging, rarefying steam pipes, &c | 3,000 00 |
| Lining upper air-chamber so as to make it water-proof, with hot and cold water pipes and sieve | 5,000 00 |
| Scaffolding and machinery | 10,000 000 |
| | $166,606 55 |

The above calculations are made at the present prices for labor and materials.

CHARLES F. ANDERSON,
*Architect and Civil Engineer.*

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*Estimates and proposals for altering and raising the roofs and ceilings of the Senate chamber and hall of Representatives; the brick walls surrounding these apartments, and the windows within these walls; the large air-chambers with their water arrangements; the air-ducts over the ceilings, and the workmanship of covering the roofs complete; also all necessary scaffolding, and temporary roofing for protecting the interior of these chambers during the progress of the work; all to be done substantially, in a workmanlike manner, and completed in strict accordance with the plans and printed specifications prepared by C. F. Anderson, architect, and subject to his approval.*

In altering these roofs, it is proposed to use the main ties in their present form, as these are known to be composed of excellent material, and to have been tested to the extent of ten thousand pounds strain to the square inch of cross section; but the rafters and braces will be altered, and made to conform to the improved roofs, and there will be seven-eighths added to the size of the rafters, so as to give to them a cross section of fifteen square inches—seven inches more than the old rafters have. This will make their strength *practically* equal to that of the ties with which they are connected, which is not the case with the old rafters; having only eight inches in cross section.

The engineer of the old roofs made a grave mistake in making the sizes of the ties and rafters nearly equal. He seems to have acted upon the theory that as the tensive strains in the ties, and the pressure in the rafters, are about equal in magnitude, and as it is known to require about equal magnitudes of positive and negative forces to crush wrought iron by pressure, and to tear it asunder by tension, that therefore the sizes of the rafters and the ties must also be equal to give to them corresponding strength. But he seems not to have considered the facts developed in practice, that rafters formed and acted upon as in these roofs, will fail by lateral deflection, under much less pressure than is required to *crush* the material of which they are composed, and that the corresponding amount of tension due to the ties cannot, by deflection, or distortion of any kind, impair their normal strength. Therefore, though *theoretically* right as to the magnitude of the forces acting in opposite directions in the rafters and in the ties, yet, in not providing for the difference in their effects, has resulted in *unscientific* construction, in roofs that have, practically, not more than half the strength that theory assigns to them. This error will be obviated in the proposed roofs by adding seven-eighths to the size of the rafters; while the ties remain unchanged.

For the purpose of ascertaining to what amount of strains the parts of the modified roofs may be subjected, and thereby determine the sizes and strength required for each part, I have made a computation of the weight of the roofs, with the ceilings, and such other parts as will be sustained by the roofs; and I find these to be equal to fifty-three pounds to each square foot of horizontal surface covered, to which I add ten pounds to the foot for possible loads of snow —total, sixty-three pounds to the foot. This is a large allowance for snow in this climate, and the high and open position of these roofs will preclude the possibility of drifts collecting upon them. The roofs, thus loaded, will produce tensive strains in the ties equal to 8,784½ pounds to the square inch of cross section, and 4,685 1-15 pounds pressure to the square inch in the rafters; which is only about one-seventh of the ultimate strength of good iron. The other parts will be similarly proportioned as to size of parts to the strains.

SENATE CHAMBER.

| | |
|---|---|
| Altering roof, raising it, and the ceiling, as per plan | $27, 979 20 |
| Gutters and eave-cornice round the raised roof | 3, 700 00 |
| Brick walls around chamber, as per plan | 11, 929 05 |
| Scaffolding and temporary roofing so as to protect the old work. | 10, 000 00 |
| Remodelling flank roofs and gutters, as per plan | 5, 000 00 |
| Lining upper air-chamber, so as to make it water-tight, with hot and cold water pipes, and sieves | 5, 000 00 |
| Air-ducts over ceiling, two thicknesses | 5, 593 00 |
| New windows around the chamber, as per plan | 3, 600 00 |
| Belt course under these windows, as per plan | 784 00 |
| Mason work in tunnel, and in new air-shaft | 20, 000 00 |
| Rearranging rarefying steam-pipes, &c., &c., &c | 5, 000 00 |
| Work on attic walls and balustrade | 37, 500 00 |
| | 136, 085 25 |

I will execute this work, as above set forth, for the sum of one hundred and thirty-six thousand eighty-five dollars and twenty-five cents, ($136,085 25,) and will give ample security for the due performance thereof.

BENJAMIN SEVERSON, 359 *E street.*

WASHINGTON, *December* 2, 1864.

HALL OF REPRESENTATIVES.

| | |
|---|---|
| Altering roof, raising it and the ceiling | $38, 970 10 |
| Gutters and eave-cornice round the raised roof | 4, 500 00 |
| Brick wall around the hall, as per plan | 13, 925 45 |
| Scaffolding and temporary roofing for protection | 10, 000 00 |
| Remodelling flank roof and gutters, as per plan | 6, 000 00 |
| Lining upper air-chamber so as to make it water-tight, with hot and cold water pipes, and sieves | 5, 000 00 |
| Air-ducts over ceiling, two thicknesses | 6, 783 00 |
| New windows around the hall, as per section | 4, 400 00 |
| Belt course under these windows, as per section | 928 00 |
| Mason work in tunnel, and air-shafts, also alterations | 15, 000 00 |
| Rearranging rarefying steam-pipes, &c., &c., &c | 3, 000 00 |
| Work on attic walls and balustrade | 37, 500 00 |
| | 146, 006 55 |

I will execute this work as above set forth for the sum of one hundred and forty-six thousand and six dollars and fifty-five cents, ($146, 006 55,) and will give ample security for the due performance thereof.

BENJAMIN SEVERSON, 359 *E street.*

WASHINGTON, *December* 2, 1864.

NOTE.—While these pages are going through the press, the attention of the committee is directed to an elaborate report upon ventilation by Messrs. Shedd and Edson, civil engineers, to a committee of the Massachusetts house of representatives, dated January 1, 1865. Copious extracts from this valuable paper are given in the succeeding pages, upon the questions of moisture in the air and the downward movement in ventilation. The views presented by this committee in the foregoing report receive, in those extracts, an intelligent and weighty endorsement. The actual and successful application of the downward movement by General Morin in the Hall of the Conservatory of Arts and Trades, and by Mr. Gurney in the Houses of Parliament, and in court-houses and other public buildings in England, must be regarded as satisfactory and decisive in favor of the conclusion to which the committee have arrived. In fact, the current of authority at this time, as well as sound reason, is for the proposed plan.

*Extracts from the report on ventilation of J. Herbert Shedd and William Edson, esquires, civil engineers, made to a committee of the Massachusetts House of Representatives, Boston, January* 1, 1865.

### MOISTURE IN AIR.

Scientific and medical authorities generally concur in the opinion that in-door air, after heating, should contain nearly the same proportion of moisture as the average of out-door air of the same temperature; but when air is brought in from out of doors at the temperature of zero, and raised by heaters to sixty-eight degrees, it would require the addition of $4\frac{348}{1000}$ grains of water per cubic foot of air to bring it up to the required degree of moisture. For the proper moistening then of fresh warmed air introduced at the rate of twenty cubic feet a minute for each one of three hundred persons two hours, the air taken at zero and at the average degree of moisture, no less than fifty-nine gallons of water would require to be added.

* * * * * * * * * *

Exactly how much vapor, or what per cent. of moisture, is the most healthy, has not yet been determined. From much observation, we have taken sixty-five per cent. of saturation as the amount most likely to prove healthy.

The mean relative humidity of the air at Philadelphia for the year 1863 was 67.2, and the mean annual average for twelve years, 68.5.

### THE DOWNWARD MOVEMENT.

The essential point of ventilation is constant change of air, the removal of the air that becomes laden with the secretions of the body, and its replacement by fresh air. In nature this change is generally effected by currents of wind that rapidly sweep away and renew the air. In addition, according as the air is cooler than the body, the portion coming in contact with the person is warmed, and, becoming lighter than the rest, has a tendency to rise and give place to new air. This tendency is shown by a sensitive wind-wheel, in low temperatures, at the distance of a few inches from the body.

The heat of the breath also has been assumed to be the special provision for its removal and replacement with fresh air. This has been a favorite theory even among scientific men. Mr. Gurney was one of the first to stoutly deny the fact; in his testimony before committees of Parliament in 1854, he asserted that the downward propulsion which the breath received by the position and direction of the nostrils did not cease, so far as the impurities with which it is laden are concerned, till it deposited them on the ground. We have not been able to verify Mr. Gurney's assertion, that on a frosty day the vapor from a person's mouth may be seen to describe a parabolic curve to the ground; but any one may see the vapor of the breath driven from the nostrils taking at first a downward course. A breath of fair strength, with the thermometer near the freezing point, may be seen by its condensed vapor, driven downward and slightly outwards, for a foot or more. The subjoined sketch is an accurate representation of the visible breath seen in air of twenty-six degrees Fahrenheit, the rate of breathing being twenty-one to twenty-two times a minute. [The figures omitted.]

In this observation, the wind-wheel moved rapidly near the body, and steadily at a distance of six inches in front, and also at two feet above the head. Notwithstanding this upward current, the breath was strongly marked by the condensed moisture, fourteen inches below the nostrils, and would doubtless have been seen further down but for the dissipation of the moisture. In a room with the air at sixty-five degrees, the same wind-wheel was in motion close to the vital parts of the body, but stopped entirely at two or three inches distance from the body, or above the head. This was to be anticipated, because the

force that carries the wheel is the rising of the air in consequence of its greater heat and lightness than that of the surrounding air, and is proportioned to the difference of temperature.

In order to determine the amount of heat operating to cause the air to rise, a thermometer was placed within the clothing near the vital parts of the body, where it was found to stand at eighty-two degrees, while the person remained in air at sixty-five; on going into air at twenty degrees, with additional clothing, the thermometer stood at seventy-six degrees. The air around the body in a warm room, therefore, would rise with a force not far from seventeen degrees, while in outer air at twenty degrees it would rise with a force not far from fifty-six degrees. In point of fact we suppose the air would rise with a velocity somewhat less than these figures, but, relatively, we think they are nearly correct. A more sensitive instrument would have been affected at a greater distance, but the same wheel showed a distinct downward motion of the breath fifteen inches below the nostrils, in opposition to all the rising tendency, by reason of the warmth of the breath, and of the air about the body; and this motion also would have been shown to a greater distance by a more sensitive wheel.

Let us now suppose, to be well within bounds, the breath to be moved twelve inches below the face. The downward motion having ceased, the upward motion should then begin which is to carry the breath up out of the way. This old breath has about one second in which to rise, from rest or reverse motion, more than twelve inches, in order to be out of the way at the next inhalation. The difference of temperature necessary to give the breath this movement of twelve inches in the first second, if the breath rises by heat alone, will surprise any one not familiar with such calculations. It is not less than one hundred and eighty degrees; that is to say, the breath, in order to start from rest and rise twelve inches in one second through air at sixty-five degrees, would have to be at a temperature of two hundred and forty-five degrees.

The absurdity to which this calculation and experiment reduce the idea that our breath is carried away from the face by its upward tendency from heat, is increased by the observation, which every one may make, that a thermometer at sixty-five degrees cannot be raised more than one degree by breathing upon it at nine inches distance, and that at ten inches no effect can be perceived. But the upward tendency of the breath is doubtless much increased from the diffusion and lightness of its aqueous vapor, and possibly from other causes, though, under the most favorable circumstances, all causes combined are not sufficient to carry the expired breath up out of the way before another inhalation, as may be seen on a frosty day; and it is evident to all that the air contaminated by the body, if carried upward, must in some measure be inhaled.

The fact, then, in regard to the removal of the expired air from the face is rather the reverse of the theory that it is carried upward out of the way. It is carried downward at ordinary temperatures with force, as of a steam-jet, that, for aught we know, deposits it with its impurities, as Mr. Gurney says, at the floor. Though we have not traced its descent more than a third of the distance, a calculation of its downward impulse shows it to be sufficient to overcome all the upward tendency of its own heat, and that of the air about the body to a considerably greater distance than that of the floor. The supply of fresh air for inhalation comes in from above and about the face, to supply the partial vacuum created by the downward jet; and in this jet, as Mr. Gurney has pointed out, not in the upward tendency of the warm breath, is the admirable provision of nature for carrying away the expelled air before more is to be inhaled.

We are not, however, to conclude that the rising force imparted to the air about a person, by heat of skin and lungs, is absolutely nothing, although in warm rooms it is practically of small account. More heat is given off from the

body by radiation than by contact of air. Enclose a person in a non-conducting cylinder not much above his size, and the accumulation of heat about him would give some force to the air. And so, in an assembly, the heat accumulated around and among the persons gives the air a certain amount of rising force. Taking for a basis Péclet's estimate of the amount of heat given off by an individual in moderate temperature, the upward force given to air by three hundred persons in an hour would be equal to the power of five pounds of coal. This is an extreme outside calculation of the force of the heat imparted by the body. If the usual deductions should be made for the wasteful manner of this application of heat to raise the air, less than half this amount of coal would be seen to balance the elevating effect on the air of three hundred persons.

Yet, on the assumption of an effective lifting power in the heat given off from the body has been based the prevailing system of ventilation—that is, of taking the fresh air in at the bottom of the room and the foul air out at the top. This is claimed to be the natural system, and, therefore, the cheapest and best. The claim is admissible in cases where no power exists to change the air except this slight difference of temperature; but what becomes of it in cases where tons of coal are burnt a day for the sole purpose of producing a power to move the air, and where, as is common, all the air taken out at the top is brought down again in pipes to the ground before being sent off through a chimney shaft? Is it not more natural, cheaper, and better to go on as nature begins, and take the foul air of breath and body directly down through the floor to its exhausting chimney?

These two theories of ventilation have been often argued and both practiced with varying success. We will consider the circumstances of a large hall of assembly, and show the operation of the two systems.

We must suppose a floor well packed with people, at the bottom of a cubical or hemispherical hall; suppose them to have entered at once, the hall being previously filled with pure air; directly the whole lower stratum of air, in which the audience are, is contaminated by their exhalations and emanations. Now, the problem is to get that stratum of air out of the hall before any of it can come to use again, and to replace it with fresh air of the right temperature. It is obvious that it cannot be taken out sideways, because then many would have to breathe over again the breath of others. It can be taken only either up or down. If it is taken up, the fresh air that is to supply its place must enter at the floor from which the foul air rises, for no air will leave a spot till other air is ready to fill its place. In order, then, to lift the whole of the foul air bodily from the floor, it is necessary that the whole floor should be open for the admission of fresh air. Wherever there is a piece of solid floor through which the air cannot pass, there will be a dead space of foul air above it, which will not rise with the rest, but will remain to be gradually mixed with the fresh air entering around it. If the dead space is considerable, the whole amount of air required must enter in the limited space of the openings, and the velocity must be proportionately increased. According as this space is reduced and the velocity increased, the air entering has a force that carries it up beyond the place where it is to be used, and mixes it with the foul air passing off; a part of which mixture will return in counter-currents and gradually replace the air in the dead spaces. The operation may be seen by a simple experiment.

Take a bucket-full of turbid water and lower it into a tub of clear water of equal temperature and density. If the bottom of the bucket could be removed without disturbance, the sides might be lowered gently and the clear water would replace the turbid water in the bucket completely, without much mixing. So, too, if the bottom of the bucket is entirely perforated, leaving very slender partitions between the perforations, the clear water may replace the turbid with little disturbance and mixing. But if the perforations are limited to holes of, say, half the space in the bottom, on pushing down the bucket the clear water

will rush up into the midst of the turbid water, and the turbid water on the solid spaces of the bottom will remain, till, mixed by friction and counter-currents with the pure water, it is gradually carried up. The fewer and smaller the holes the longer the turbid water will remain in the dead spaces; and, if its turbidness is from a constant source, it will be likely to increase rather than diminish.

Dr. Reid, the most scientific and experienced, perhaps, of the advocates of the upward system, seeing this necessity for introducing his fresh air through the whole extent of the floor, when, after experience in the temporary houses of Parliament, he was called upon to arrange the ventilation of the new House of Commons in Westminster Palace, had the entire floor made of perforated iron. This was afterwards covered with haircloth carpeting, and through nearly its whole extent the fresh air was admitted. No expense was spared, and the system was tried for some years under the most favorable circumstances. The result was, that, on account of the raising of dust by the entering air, and still more on account of the uncomfortable draughts brought up against the honorable members' legs, nine-tenths of the floor came to be covered with sheet lead under the carpet. And when the entrance for fresh air was thus limited, it being through the carpet but a fraction of the nominal extent, complaints became so loud both of strong currents and of foulness of air, that the whole matter of ventilation was turned over to Mr. Goldsworthy Gurney, who undertook it on the opposite system of introducing the fresh air above and taking out the foul air at the floor.

In the French senate chamber, formerly supplied with fresh air through the rising steps behind the members' seats, these openings were closed because of the draughts about the senators' legs, and, according to Morin, in 1862 they had no ventilation at all.

Such are some of the difficulties of changing the air of a crowded hall by introducing it at the bottom and taking it out at the top. To avoid them, Sir Charles Barry, the architect of the new houses of Parliament, introduced his main supply of fresh air in the House of Lords through the middle compartment of the ceiling, expecting it to descend to the floor, then to rise at the sides, and to be taken out in the side compartments of the ceiling. This was expecting too much of atmospheric nature, and, after a few years' trial, this hall, too, was given over to Mr. Gurney, who proposed to take the air out at the floor. We shall not dwell on the system of taking both the fresh air in and the foul air out at the top, or on that of taking the fresh air in and the foul air out at the bottom, because these systems, to be equally effectual, must double the amount of current that would be caused by taking the air in one way and out the other, and are for that reason not to be recommended for large halls, where the great difficulty is to change the air fast enough without making unpleasant currents.

Introducing the air at the upper part of a hall, and taking it out at the bottom, known as downward ventilation, has certain obvious advantages: 1. It takes the emanations of the skin and lungs out of the room immediately after they are given off, before they have a chance to be inhaled. 2. Consequently, the fresh air coming unimpaired directly to the heads of the audience, a much less supply is required to secure the freshness of what is inhaled than is necessary when the new air is brought first to the feet, or becomes mixed with foul currents. 3. The warm air introduced has the opportunity of spending something of its heat on the ceiling and walls before it comes to be breathed, instead of being breathed at its highest temperature. 4. The fresh air is diffused over the whole area of the hall, even if introduced through few apertures, before reaching the audience; by which means the air is brought upon them more gently than if it came directly upon them through limited apertures. The greater the number and area of apertures for the exit of the foul air at the

floor, the better, and the less will the current be felt. But this current, being downwards, will always be felt in a much less degree than a similar current upwards about the legs, for obvious reasons; and the dust and odors of the floor will be carried down, instead of up into the air to be breathed.

For illustration of downward ventilation, take, as before, a bucket of water, turbid near the bottom, and sink it in a tub of clear water. Suppose the bottom to be well perforated, or even but partially so, clear water coming in at the top, as the bucket is raised, will force out the turbid water very effectually at the bottom, whatever may be the position of the openings at the top. In other words, air passing through a room will drive out more thoroughly and uniformly the air at the side at which it goes out than that at the side it enters.

The gain effected by bringing the fresh air to the face, to be breathed before it sweeps the body, is quite important. It may be estimated by considering how much less supply of fresh air would be sufficient for a man enclosed in a cylinder just large enough to hold him, in case the air came down to his head first, than in case it came to his feet first, and up by his body to the face. A crowded assembly may be considered as a set of such cylinders, closely packed together, with their occupants like bees in their cells. The great advantage, in point of economy of freshness, of sending the air downwards, instead of upwards, is here very apparent; and it is obvious that in the one case may be obtained perfect purity of the air, while in the other it can never be more than an approximation.

The heating of the walls, ceiling, floor, and furniture of a hall is of great importance. Otherwise, very hot air will not suffice to keep the occupants comfortable. If, as in most cases, this heating is to be done by the warm air alone, the more there is accomplished before the air is breathed, the less will be the comparative heat of the air entering the lungs.

This we consider, in itself, a decided advantage, and it is obtained in greater degree when the warm air is introduced above than when it enters at many points through the floor.

When the air is introduced at the top of a hall and drawn out at the bottom, it is rapidly diffused through the whole upper space, and then begins to descend slowly and very uniformly to the floor. This is the case even at present in our representatives hall, where the warm air enters at a single opening above the Speaker's chair. This air rises at once into the dome of the hall, as seen by experimental balloons, where it is quickly diffused, and then descends almost vertically in all parts of the hall to the floor. This arrangement, though designed only as a temporary and experimental step to the still better plan of introducing the air directly into the dome, proves, in a degree, that much greater gentleness and uniformity of motion, with freedom from needless currents, may be obtained with downward ventilation than it is possible to have with upward ventilation. For, in the latter, the rising air can occupy but very much less space, must have, at the level of the audience, proportionally greater velocity, and must alternate with additional counter-currents.

The objections to the downward system are: 1. Its supposed antagonism to the natural laws of upward movement of heated air. 2. The supposed greater heat of the upper air in the hall under that system.

The first objection we have already sufficiently considered. Practically, even those who favor upward ventilation admit that there is no difficulty in taking the foul air out at the bottom by the application of a moderate force; and nothing in the art of ventilation is more universally admitted than the necessity, under any form of ventilation, in all public buildings, for the employment of some special power.

Nor is the objection strengthened materially by the common impression of greater foulness at the top than at the bottom of a crowded room. There is some truth in this impression, in regard to rooms which have no ventilation, though

most careful experiments by eminent chemists fail to show any considerable or uniform increase in carbonic acid in the upper part of crowded halls; perhaps as many experiments have shown the greater amount at the bottom as have shown it at the top. What slight increase there may sometimes be at the hottest state, is probably more than lost as the heated carbonic acid cools, and, to some extent, sinks from its weight. Sensitive observers, too, have found that though the upper portion of a heated, ill-ventilated hall smells most offensively, and, from its heat, is oppressive, the lower portion most seriously affects their state of health. In our representatives hall, there has been the most serious complaint of oppression on the lowest portion of the floor, around the Speaker's desk. In point of fact, we believe, the idea of the greater foulness of air at the top arises mainly from crowded evening assemblies, where the heated products of combustion from gas-lights contaminate the upper air to a great extent.

It is of the utmost consequence that these products should have some direct means of removal. This is provided for in the best ventilated halls by so disposing the gas-burners that they may have direct and independent outlets for their smoke and gas. Another obvious explanation of the frequent greater impurity of the upper air in crowded, ill-ventilated halls, is that, without special force of supply, there is always a rush of fresh air into the hall through the doors as they are frequently opened; this air being cooler, of course, forces the warm foul air upwards. After all, the greater heat at the top of the room is probably the chief cause of the impression of greater foulness, though with the heat may be associated some light odorous gases. But all this is of no importance against systematic downward ventilation. When the foul air is taken off at the bottom, it is no longer found in excess at the top.

Morin's very accurate experiments in the smaller hall of the Conservatory of Arts and Trades, ventilated from above downward, show, on the average, a scarcely perceptible difference between the temperature of the air above and that below. In our own representatives' hall, where now the warm air is introduced thirteen feet above the Speaker's platform, and the foul air taken out at the floor, though the arrangements for supply and exhaust are, at present, quite limited and much less than we should desire, we have found as the average of over five hundred observations in eighty-six different positions, with the exhaust ducts open, the temperature opposite the gas-burners above the gallery only about two and one-half degrees above the average throughout the hall; while that of the lower seats was not two and one-half degrees below the average. When, however, in the midst of these observations, the exhaust ducts were temporarily closed, the difference soon doubled, though the whole average temperature was slightly lowered.

To give these results more in detail:

| Observations in level planes. | Ventilating ducts. Open. | Ventilating ducts. Closed. |
|---|---|---|
| Average in dome of hall | 78.5° | 85° |
| Average opposite gas-lights above gallery | 71.46° | 73.54° |
| Average opposite gas-lights below gallery | 68.57° | 66.50° |
| Average in the seats | 66.63° | 63.72° |
| Average throughout the hall | 68.86° | 68.17° |

It is essential to the system of downward ventilation, as well as to all other systems, that a constant current should be maintained by keeping the inlet and outlet always open. When less heat is desired, the change must be effected, not by stopping the warm-air inlet, but by letting into it cooler air. And when the heat of the room goes off too fast, especially when it is empty, the heat

may be economized by letting the air at the floor back into the heating chamber instead of out of doors.

In support of the downward system, we will only refer to Mr. Goldsworthy Gurney's testimony before the committees of both houses of Parliament, who has for the last ten years had charge of the ventilation of the houses of Parliament, and who has introduced the downward system with great success, in court-houses and other public buildings, in England; to the book of Mr. Ruttan, of Canada, who has introduced the system most successfully in railway cars, on some of our roads, as well as in buildings; and to the conclusions of General Morin, well known for his valuable scientific works on different departments of engineering, and the author of the latest and most elaborate work on ventilation, (Etudes sur la Ventilation, Paris, 1863, 2 vols. 8vo, pp. 1017.)

General Morin says, in treating of the ventilation of large halls:

"The numerous observations which I have gathered, and which any one may repeat, have shown me, as I have already said, that there are very sensible inconveniences in making the new air, warm or cold, enter near the occupants of a hall.

"This air is always necessarily at a temperature different from that of the hall; warmer, if it is desired to raise or even sometimes to maintain the inside temperature, as is the case in winter, to compensate the cooling effect of the walls, and when there are few present; and, on the other hand, cooler, if the outer temperature is somewhat high, and if there are many occupants.

"In the one case, as in the other, the neighborhood of the apertures for the entrance of air is disagreeable, and, whatever care is taken to limit the velocity by giving the apertures the greatest possible extent, it is seldom that the velocity can be less than 1.3 to 1.7 feet per second, from which there is sometimes an uncomfortable sensation."

After referring to the experience in the English House of Commons, and to that in the French senate chamber, in both of which the apertures for the admission of air had been gradually closed, because of the objectionable currents, till ventilation had almost ceased, General Morin continues:

"It does not seem to me, then, suitable for amphitheatres, or for any other place of a similar kind, to admit the new air through the floor, by the steps or the step-risers. On the contrary, here as elsewhere, the air should be made to enter as far as possible from the audience; and as it may be often necessary the same day, and from time to time, to vary the temperature of the air admitted, within certain limits, arrangements must be adopted which will render the mixing of warm and cold air as complete and as easy to modify as possible, before it comes in contact with the audience. This, it must be said, is the most delicate condition to well fulfil, and amphitheatres are, perhaps, the case in which the difficulty is presented in the highest degree.

"After having reflected much and observed well the various effects of the introduction and evacuation of the air, this is the solution which has seemed to me the surest, and which I have settled upon for the amphitheatres of the Conservatory of Arts and Trades. It has already been applied to one of them as completely as the local conditions would permit in a building of old construction. The vitiated air being that which it is necessary to draw out, it is desirable to hinder it from diffusing in the hall, and consequently to extract it at the spot where it is vitiated, that is to say, as near as possible to the individual occupants, through perforations, in the risers, or backs of the steps, in order to make it pass out under the amphitheatre.

"The introduction of fresh air presents two principal phases, quite distinct.

"In the first, which precedes the arrival of the people, the amphitheatre should be brought up to a moderate temperature, which may, however, be raised to 64.4°. At this moment it is evident that the movement of air from inside to outside of the hall should be, in general, completely interrupted; and in order

that there may be established throughout the hall a suitable temperature, it seems natural to allow the warm air to be introduced then by passages communicating with the heaters and opening through the floor at the lowest points.

"In the second period, on the contrary, soon after the entrance of the audience, and according to their number, more or less, we must extract a portion of the air now vitiated and more or less heated, and replace it with pure air. But this fresh air would be, as is daily observed, very uncomfortable if its temperature were much lower than that of the air of the hall, and especially if it flowed in too near the audience.

"From this results: 1. The necessity of introducing the fresh air first into a receiver, which we call the mixing chamber, where, by the simultaneous entrance of hot air and cool air, in proportions which can be easily regulated, the means are kept of admitting into the hall only air of the desired temperature. 2. The obligation, not less imperative, to place the openings for the admission of this fresh air as far as possible from the audience, that is to say, about the ceiling of the amphitheatre, if the circumstances of the place permit, or at least at a considerable height. In general, whenever the construction will permit, it is preferable to bring the fresh air through the ceiling or the cornice by openings so proportioned that the mean velocity of the air will not exceed 1.3 to 1.7 feet per second."

The general rules adopted by Morin are as follows:

"1. Place the exhaust orifices as near the points where the air is vitiated as possible.

"2. Have as many orifices of exhaustion as the construction of the building will admit of.

"3. Orifices of exhaustion should be so proportioned that the velocity of air passing through them may be from 2.6 to 3.3 feet per second.

"4. Unite the different groups only by entering them into the common conduit, or into the chimney of exhaust, and as far as possible from their openings into the rooms. Arrange in such a manner that they can be easily examined and repaired. Protect from cold.

"Do not place the orifices for the entrance of fresh air near the floor; it is proved, in the French Senate, that where the orifices were near the floor, currents of *warm* air, having a velocity of from one and three-tenths to one and seven-tenths feet per second, were disagreeable; currents of cold air should be avoided for much stronger reasons.

"The above is agreeable to the conclusions of both French and English engineers."

The whole discussion of the matter of ventilation before committees of Parliament for twenty years, ending some ten years ago, is full of interest and instruction; through it all Mr. Gurney appears in behalf of downward ventilation, in opposition to Dr. Reid, who, for that time, was attempting to ventilate the houses of Parliament satisfactorily on the upward system. When, in 1854–5, the committees of both houses determined to give their ventilation into the hands of Mr. Gurney, they seem to have adopted the conclusion of Mr. Robert Stephenson, who, himself a member, was examined by a committee of the House of Commons in 1852, and testified that for a crowded hall he preferred downward ventilation, unless the gas-lights should interfere; and that it was as easy to draw the air out downward as upward.

Dr. Morrill Wyman, whose little treatise on ventilation contains more scientific and sensible information on the subject than almost any other book in the English language, though he gives assent to the prevailing theory of upward ventilation, says:

"There is no impossibility, however, of producing a constant and equable downward movement, which shall also effectually prevent all respired air from being again presented to the organs of respiration. The first movement of expired air

is from the mouth, horizontally, and from the nostrils, downward, before it begins to rise; consequently, a downward current may, without much difficulty, be brought to bear upon and remove it."

As regards the manner of applying power to effect the change of air, it is sometimes applied to the exhaustion of the foul air, and sometimes to the supply of fresh air. Either way is effectual in a degree, but neither alone accomplishes quite all that is to be desired. Forcing the fresh air in abundantly will drive out the air already in the hall at every outlet, and it is essential for security against the intrusion of cold currents through cracks and doorways. But it will drive the air out mainly at the easiest outlets, and some of the most important may be neglected, because of being out of the easiest way for the air to pass. The only sure way to get the air out just where you want it to go out is to apply an exhausting force at the outlets, to guide and assist the expelling force. The filling method is called the plenum method, and the exhausting the vacuum method. Much has been said about the superiority, for working vigor, of air in a plenum, or over-pressure condition. There is no doubt of the fact that under a high atmospheric pressure a man has greater power than under a low pressure. But the amount of superior pressure that can be obtained in a common hall is very slight, and can hardly have a perceptible effect. A nearly even balance of the filling and exhausting forces, making the in-door barometer about the same as the out-door, but with the filling force enough in excess to keep out all air seeking to enter without leave, is the most economical and satisfactory condition to obtain.

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## EVIDENCE.

WEDNESDAY, *January* 25, 1865.

Committee met at 7 o'clock p. m.

Present:

Mr. BUCKALEW, chairman,
Mr. HOWARD,
Mr. PIKE.

Dr. THOMAS ANTISELL called and examined.

By the chairman:

Question. State whether you have examined the plans of Mr. Anderson which are before the committee.

Answer. I have examined his plans, and I have also read his paper explanatory of them.

Question. I will ask you in reference to shafts outside the building, say thirty feet high, for obtaining the air in the first instance; whether that plan is eligible, and what would be its advantages over the present system of obtaining air from the level of the terrace?

Answer. I do not think a shaft of that height is necessary, because this building is placed so far above the average surface-level of the country as to relieve the air from the effect of immediate contact with the ground. The air lying immediately on the ground without motion is cool for three or four feet, and therefore a shaft three or four feet high would be all that is needed. A high shaft is objectionable in consequence of increasing the friction caused by the air passing through it; of course requiring increased power to overcome the friction.

Question. Would there not be an advantage in shafts of some elevation in order to avoid the dust and dirt?

Answer. I think not. You would have to go higher than twenty-five or thirty feet to give any considerable protection against dust.

Question. Then the degree of effect produced in that regard would depend upon the height, would it not?

Answer. The height of twenty-five or thirty feet would not produce much difference in respect to dust. We should not take air from the immediate contact with the ground, which is cold, but three or four feet elevation would obviate that difficulty.

Question. Would there not be some impurities contained in the air within three or five feet of the ground that it would not contain twenty-five or thirty feet above?

Answer. I do not think there would be any material difference.

Question. I understand you to speak with reference to the particular location of the Capitol?

Answer. I am speaking with reference to this particular point or place.

Question. That you are not pronouncing a general judgment, but applying your opinion to this particular case?

Answer. Yes, sir.

Question. With regard to the second point in these plans, of providing a jet or jets of water near the entrance where the air is drawn into the building, the jet projecting into the current of air, is that, in your judgment, an idea of utility and value, or not?

Answer. That, I believe, is no part of the original plan. It would remove any existing carbonic acid that might exist in the external air, but would not, I think, remove any solid bodies the air might contain.

Question. In reference to the power proposed for propelling the air toward the halls, Mr. Anderson suggests the erection of a fan for that purpose; I desire to know whether, in your opinion, that is a proper instrument?

Answer. It is the most effective, but not the most economical. The chief power should be placed at the point where the air is thrown out or removed from the building. I look upon the first fan as of secondary importance, compared with the fan which is placed at the point where the air is removed. The object is, to remove the air that has become impure; and it may be done much easier and with more certainty if the power is applied at the removing point.

Question. Would a fan be the proper means, in your opinion, of accomplishing that object?

Answer. I think it is the most effective power for a building of this magnitude. There are other kinds of power sometimes used; such as the aspirating power, applied by means of fires in chimnies, causing the expansion of the air, and the ordinary mode of doors and windows, which is impracticable in the present arrangement of this building.

Question. Then the question is between fans and chimnies?

Answer. Yes, sir.

Question. In admitting the air into the chamber above or below, what is your opinion of its admission by diffusion through numerous openings?

Answer. That would be a necessity; otherwise, in admitting the amount of air required for these large rooms, a terrible current would be created. It is necessary that it should be distributed.

Question. In short, its distribution at the time of entering the room is necessary for successful ventilation?

Answer. Yes, sir; the amount of air required for a single person in a public room is a thousand feet an hour; and the introduction, in a single current, of the air required for one of the chambers in this building, would produce a perfect whirlwind.

Question. With regard to the mode of exhausting the air or removing it from

the halls, do you speak of the fan as the most efficient power for accomplishing that purpose?

Answer. Yes, sir; it is the most effective.

Question. What is the effect upon the character of the air of taking it, as we do at present, at a temperature of 30°, passing it through a closed dry space, heating it to the temperature of 75°?

Answer. By increasing the heat 45° the air is expanded forty-five four hundred and eightieths, or one-twelfth of its bulk. The result of that expansion is, that the same quantity of water which was in a cubic foot originally is now in a cubic foot and a twelfth. The moisture is therefore relatively diminished, and the air becomes drier. The fact that air becomes drier in the process of expansion constitutes one of the great difficulties in ventilation.

Question. Is not the air very much changed in reference to the moisture it contains, by this process, from the condition of the external air at the same temperature?

Answer. The quantity of water in the external air depends upon the temperature, and upon nothing else. There is a certain amount of water in a cubic foot of air at a temperature of 75°; being a little more than four times as much as is contained in a cubic foot of air at 32°.

Question. Is it necessary then, in cases like that of our building, in order to secure the proper condition of air in the chamber, to hydrate it?

Answer. It is.

Question. How, in your judgment, can the hydration of the air passing into these chambers be accomplished most efficiently and conveniently?

Answer. It may be heated most readily by passing it against furnaces of red hot plates; but that burns the air, and it is objectionable on account of the odor. It may also be heated by passing it over hot water or steam pipes.

Question by Mr. Howard:

What do you mean by *burning* the air?

Answer. I mean that as the air ordinarily exists it contains microscopic forms of animal and vegetable life; these are burnt when thrown upon the surface of red-hot plates, and the air is thereby injured.

Question by the chairman:

I wish to call your attention particularly to the most convenient and efficient mode of imparting moisture, artificially, in our arrangements here.

Answer. I think that sprays of water, at the ordinary temperature, or slightly increased, thrown at right angles to the currents of air would be the most effective mode. If thrown directly against the current it would too much impede its force, and require too great power to overcome it. Passing it at right angles is the natural mode by which the air is moistened. Many a shower falls above which never reaches the ground, thus showing that sprays of water are absorbed by the air.

Question. Will you state whether admitting the air to a chamber by diffusion through the floor is not liable to the objection that a considerable amount of dust and solid matter is carried up into the atmosphere of the room?

Answer. Certainly; the current of air carried upwards through the floor would take with it the dust upon the carpet or floor with which it came in contact, and for that reason that locality for admitting the air has been given up in nearly all large buildings. It is generally admitted from the sides, near the floor, but not through the floor.

Question. Do you consider the application of power for the removal of air from a chamber more important than for its introduction?

Answer. Certainly; that is the main point. The main power should be applied where the air is to be removed, and for this reason: you are never sure in

driving air in, that it arrives at the point desired; but if you take it out of the room the thing is palpable.

Question. In a room occupied by a large audience, sitting for several hours, is there not a very large amount of carbonic acid gas generated?

Answer. A very large amount. The extent to which the air is affected by it, however, depends upon the closeness of the room.

Question. At what temperature would that be thrown into the atmosphere from the lungs?

Answer. At very nearly 90°, sometimes at 85° in the winter time.

Question. In other words, it would exceed the temperature of the air in the room on ordinary occasions?

Answer. It always does.

Question. And the result would be that that gas would ascend in the room?

Answer. Yes, sir.

Question. Assuming that it would come in contact with a comparatively cool surface, such as the sides of the room, or windows, or glass roof, what would be the effect upon the gas?

Answer. Its temperature would be lowered to that of the surrounding air, and it would pass up or down, as the case might be, with the currents of air in the room.

Question. When of the same temperature as the air, is not this gas heavier than air?

Answer. Two and a half times heavier, when pure. That thrown off from the lungs, however, not being pure carbonic acid, is not so heavy as that.

Question. I understand you that carbonic acid gas, upon coming in contact with a cold surface on ascending, is liable to be thrown into the air, to be again breathed?

Answer. Certainly; it is very liable to the power of diffusion.

Question. Is not that one of the reasons why an efficient mode of removing the air from the room by a power appropriate to the purpose is necessary?

Answer. In all rooms there is a necessity for force to remove the air, because air has a tendency of itself to remain still. Even while resting upon the ground it will not move unless there is a wind to force it. It is absolutely necessary that it should be removed by force.

Question. Have you reflected upon the subject of the effect of this large area of glass roof over the two chambers of Congress upon the ventilation of the chambers; the air and gases being admitted to immediate contact with the roof through perforations in the ceiling; what would be the effect of bringing it in contact with the roof at this cold season of the year?

Answer. When a glass roof to a building is made use of, it must be for the purpose of admission of solar light, and as this agent is always accompanied by heat, these two agents always are introduced together, and it is because they are so introduced that this plan is adopted by horticulturalists. A glass roof converts a building into a green-house and destroys the advantage of a roof, whose design, in domestic structures, is to be a defence against the alternations of season and changes of temperature. Glass is especially pervious to the rays of solar heat, and hence in summer time admits a great amount of heat. If the air space be in direct communication with the air in the rooms below, the whole air will of course be heated up much higher, and if the air drawn in had been previously cooled it would heat it again. If the vitiated air had to pass through such air space, it would become so heated and expanded that its current outward would be impeded, and deficient ventilation be the result.

In winter time a glass roof would admit only light, and it would, to some extent, diminish the temperature of the air in the air space, and if the ventilation were to be carried on by the plan now proposed by Mr. Anderson, such material for the roof would be objectionable as being a greater cooling agent than the ordinary materials of a roof.

Question. What do you say as to the construction of windows, if they were to be placed in our halls; should they be single or double?

Answer. Windows are for light; they should never be designed, primarily, for the admission of air, and therefore should be double, so as to protect the room from the influence of external heat and cold.

Question. I desire to ask you, having looked at Mr. Anderson's plans, whether the introduction of air at the ceiling and its removal at the floor is feasible, and likely to effect the object designed by it?

Answer. It is feasible, certainly, with sufficient power applied. It is against the natural tendencies of air; it is contrary to gravity; and so far requires additional power to overcome the natural tendency of heated air to rise. If the plan were varied so as to admit the heated air from below, and escape above, I think it might be an advantage, as it would consult the natural tendencies of the air. In regard to the object that might be gained by this reversion of the current from above, downwards, with respect to sound in the room, I must speak hesitatingly. My impression is that not much would be gained by this reversion of the current. It is true that a strong current of air will, to a certain extent, affect the passage of sound. A person speaking against a strong current of wind will be heard more distinctly in his rear than from the same distance in front. But in this case the current would not, I suppose, be stronger than three or four feet in a second—more than that would create a breeze that would be objectionable—and as sound passes 1,180 feet in a second, the advantage, if any, would be very slight. If the air can be kept perfectly still, I believe that is a condition most favorable for hearing. It is for that reason that the old Gothic churches are more favorable in respect to acoustics than large square rooms. This plan, however, has never, to my knowledge, been tried, and therefore, I say, I cannot speak confidently. I do not wish at all to impress my opinion upon the committee as to the effect of the downward current upon acoustics, but my impression is that the difference would be slight in the point gained, while the disadvantage would be more decided in overcoming the natural tendencies of air.

Question. Have you ever made experiments, which are in your recollection, as to the amount of force necessary to move a column of air downward in a given space, so that you could speak as to the general application of Mr. Anderson's plan in this respect?

Answer. I have made no such experiments. It is a complicated question. A certain amount of air is driven in by the first machine. It is then heated, and its bulk increased at least one-twelfth, in the plan proposed, by rarefication. A larger amount of air is therefore required to be removed, and more power must be applied to the exhausting fan.

SATURDAY, *January* 28, 1865.

CHARLES F. ANDERSON, architect, examined.

By the chairman:

Question. Will you state your views of the western projections of the Capitol wings?

Answer. In the plan I made for the new wings I brought them forward toward the east so as to commence them on hard ground, thus avoiding the new embankment. Another reason for doing so was to complete the outline of a Roman building, as the old Capitol was of Roman architecture, so as to provide a court-yard in front on the east. We have numerous authorities for that arrangement. I gave in my description to President Fillmore, at the time, as authority, Buckingham palace and St. Peter's at Rome, both of which have large court-yards, and, in fact, I gave different private residences in which many of the nobility lived, as illustrations. There is really hardly a regular Roman building that

has not a court-yard in front. These court-yards are generally entered through a triumphal arch. The college of architecture in which I studied was a Roman structure built by the Duke of Leinster for his own mansion. It was an extensive Roman building, something like the Capitol, but with a large court-yard in front, entered by a triumphal arch of peculiar beauty. I could give numerous instances of the same kind. The first time I saw the effects of building these wings on the original surface below the new embankment was immediately after the House was roofed and before it was plastered, which was about the time Mr. Buchanan came into office, at the commencement of 1857. I found the west brick wall of the Senate wing cracked from top to bottom; the crack was widest at the top and large enough to put your hand in. I afterwards saw it filled up with brickbats and mortar. I next observed that the north side of this west corridor, opening on the west side, had opened from end to end. They stopped it up; it opened a second time, and I saw them stopping it the second time with plaster of Paris.

By Mr. Howard:

Question. How long time intervened between the first and second time?

Answer. About two years. I next observed an opening in the joints of the marble work on the north end. I was present when the men were stopping up these openings, and saw them stopping them up and pointing them up to hide them. General Franklin's report to Congress, under date of November 6, 1860, (a report on the Capitol,) states, that "in July last the levels of the cornice of the two wings of the Capitol extension were taken. It appears from the levels that, at the top of the granite basement cornice, the west side of the south wing is four and one-eighth inches lower than the east side, and at the corresponding point on the north wing the west side is two and seven-eighths inches lower than on the east side. These figures are given, not because any danger is anticipated, but only to place the data on record in permanent form." I recommend that you finish these arcades with cornice and balustrade at the top, which will produce a good architectural effect, by carrying out the principles of Roman structure, more fully than to finish them as heretofore proposed; inasmuch as they never intended to put a portico there, but merely a colonnade over the arcade. They intended to carry round the entablature on that colonnade—the same entablature that they have on the end of the building. The effect of it would be simply this: a column before each pilaster has no object of any kind affected by it. It involves an additional expense of marble work, and excessive weight, without any possible advantage. Standing at right angles with the building, these columns would not be seen more than the pilasters would standing by them; they merely obscure the pilasters and deprive the numerous offices on each side of the building of air and of light; it being an object in architecture never to introduce an ornament without a purpose and object. In every well-designed architectural building there never is an ornament introduced that has not its object, which this feature of the design of the Capitol has not. The same observation is applicable to all of the four colonnades—north, south, and two west—with this exception, that there is no necessity for precaution in respect to weight on the north and south sides.

By the chairman:

Question. Is the proposed work you have spoken of very expensive, according to the present design?

Answer. There have been two appropriations made for finishing the steps and portico of the building on the east side. There has been one appropriation of $300,000 for finishing these four colonnades, no part of which has been expended. The only way I can get at the price of that work is the amount of that appropriation. I went to the Register's room, where the agreements for

this work ought to be filed, and got a certificate from the officer there that they never had been filed. I could not, therefore, give their exact price. The cost of the balustrading would be exactly the same as that already on, for it would have to conform to it.

Question. But you cannot state what that would be?

Answer. No, sir; no account has been filed of what anything cost, and, therefore, I cannot state precisely. It would be a great deal cheaper than the other plan, and it would, at the same time, admit more air and light. It may not be out of place for me to remark that, although this marble attic which I propose to erect around the two wings will add weight to the building, it will be on a perpendicular line with the building itself. It will not involve any leverage, as these columns do. Then, again, let me remark, that the attic need not be built while the ceiling is being raised and the windows inserted; that is to say, you can finish the ventilating arrangements without making the change required in the outside of the building, and afterwards the outside work can go up while you are sitting in the chamber.

Question. I will ask you as to the general appearance on the building of elevating the wings as you propose, and the reasons for doing it, in respect to the architectural appearance of the building?

Answer. The old building being Roman Corinthian architecture, it was essential, in carrying out the style, to break the sky-line of the building so as to form an irregular line. One of the principal differences between Roman Corinthian and Grecian Corinthian is, that Roman architecture must have a broken sky-line, while the Grecian must have a horizontal line. The Roman building must have balustrading, the Grecian building must have none. Whenever there is a deviation from these rules you have what we term bastard architecture and not pure architecture. I refer you to the Post Office building, which is Grecian Corinthian with no balustrading, and also to the Patent Office, which is a Doric building of Grecian architecture. The Treasury building, with its columns on part of it, was intended for Grecian Ionic, but they went and put a balustrade round it and broke up the architecture and made it a hideous thing.

Captain RICHARD R. MOFFATT called and examined.

By the chairman:

Question. State whether you have studied architecture.

Answer. I studied it while in the west.

Question. I will ask you, if you have examined the subject, your opinion as to the architectural effect upon the Capitol building of an elevation of the wings?

Answer. I have taken a great interest in architecture, and have paid particular attention to the Capitol building. I find in it a long-continued line of cornice without break. I think such an elevation as is shown will add to its beauty, giving it a more Roman Corinthian style of architecture. It will add not only to the appearance of the exterior but to the interior of the building. I think, in the hall of the House of Representatives particularly, the ceiling is too low for acoustics or proportion.

*January* 31, 1865.

Examination of WILLIAM FORSYTH, of Washington, D. C., city surveyor.

By the chairman:

Question. State whether you took the levels of the Capitol wings to-day?

Answer. Yes, I have taken the levels of the north and south wings this afternoon.

Question. State how you found them.

Answer. I found that the northwest corner of the north wing is 2½ inches lower than the northeast corner of the same wing. I found also that the southwest corner of the south wing is 4½ inches lower than the southeast corner.

Examination of ISAAC BASSETT, of Washington, D. C.

By the chairman :

Question. State whether the two papers shown you are statements of temperatures in the Senate chamber taken under your superintendence at the dates mentioned?

Answer. Yes, sir.

Question. Are they correct?

Answer. Yes, sir, as far as I see.

Question. They were taken by request of the committee?

Answer. Yes, sir.

[The statements are annexed to this record.]

Examination of Dr. JOHN A. ROWLAND, of Washington, D. C.

By the chairman :

Question. State how you are employed.

Answer. I am employed as clerk in the Attorney General's office.

Question. State whether you have experimented by adding moisture to the air of the office?

Answer. I have in some of the rooms during the present winter and the winter before. I have added moisture to the atmosphere with good effect by evaporating water in the rooms. It has produced a very great improvement in the air of the rooms, and I have no doubt that such a statement would be made by the Attorney General and his assistant. I have heard them both remark very favorably upon it.

Question. State whether you have examined works on the subject of moisture in the atmosphere, and have made out a statement of citations which you now submit to the committee?

Answer. Yes, sir. This statement is from what I believe to be reliable authority.

[The statement is annexed to this report.]

Witness. The office of the Attorney General is located in the south wing of the treasury building; it is warmed by heated air sent up into the room through flues. To counteract the dryness of that air we introduced gas stoves by which we evaporate a large quantity of water during the six or seven hours we are there—say two or three gallons in each room. The rooms are twenty and twenty-two feet by fourteen feet high. We found that to improve the comfort of the rooms very much. When the room seems supplied with moisture the openings for the escape of the air are permitted to act. The opinion at which I have arrived in respect to it is, that in these rooms, even with the large amount of water we evaporate, there has not been any day too much moisture. It seems that the more we have been able to evaporate, the more comfortable have the rooms been. I have arrived at a strong conviction that if, in addition to heating the air, the feature of introducing the necessary amount of moisture were adopted, the air in the rooms would be as comfortable as the air out of doors is at the same temperature.

The chairman submitted the following statement of temperature in the Senate chamber, as observed by him, the observations being made from a thermom-

eter on the right hand side of the president of the Senate, and from one opposite on the south side of the chamber:

| | | | | |
|---|---|---|---|---|
| January 19, | 12½ o'clock, | 69½; | 2½ o'clock, | 70. |
| | | 74. | | 75. |
| January 25, | 2 o'clock, | 70. | | |
| | | 75. | | |
| January 27, | 3½ o'clock, | 71. | | |
| | | 75. | | |
| January 30, | 12½ o'clock, | 70½; | 4 o'clock, | 69. |
| | | 76. | | 72½. |
| January 31, | 12¼ o'clock, | 70. | | |
| | | 74½. | | |

Examination of CHARLES B. CLUSKEY, of Washington city, D. C., architect and civil engineer.

By the chairman:

Question. How long have you been engaged in the practice of your profession?

Answer. About thirty-four years.

Question. Have you been frequently employed in the examination of public buildings and public works?

Answer. I have.

Question. And of government buildings?

Answer. I reported on the government buildings here for the Committee on Public Buildings of the 30th Congress, which report is numbered 90.

Question. Have you examined the wings of the Capitol and determined what settlement, if any, has taken place in their foundations since reported on by Captain Franklin?

Answer. I have; and with the exception of the foundations of the steps on the west end of the south wing, no material settlement has taken place of the foundations proper of either wing since the report of that officer.

Question. Have you examined the plans prepared by Charles F. Anderson for improving the architecture of the exterior of the Capitol, and the heating, ventilating, and lighting of the halls?

Answer. I have.

Question. I desire to ask your opinion as a professional man as to the effect of elevating the wings by an attic, both as regards the architecture of the whole exterior, and the lighting of the halls through windows in the proposed inner attics instead of the present sky-lights in the roofs?

Answer. The architectural effect would be essentially improved by an attic on each wing, as they would give elevation where required, and break up the present continuous horizontal sky-line; and I would further suggest, that if the roof of each wing, when raised on its attic, was surmounted by a semi-dome (cupola) harmonizing in detail with the dome proper, and all projections above the line of the balustrades of the old building removed, and increased projection given to the east portico, so as to correct the defect created by the excessive proportions of the dome, the magnitude, grandeur, and unity of the whole composition would be greatly improved. As it regards the lighting of the halls through windows in the inner attic walls in place of the present skylights, the effect would be to give height of ceiling, illuminate the halls uniformly throughout, give to them a cheerful instead of their present gloomy appearance, and shut out the noise created during heavy rain or hail storms, which frequently disturbs the progress of business.

Question. Would you recommend the windows to be made double?

Answer. I would.

Question. What object would be accomplished by that?

Answer. Double sashes, properly constructed, with a space between them, would aid very materially in preserving the uniform temperature of the air in the halls in both winter and summer.

Question. What other benefit would be gained by windows over the present skylights?

Answer. The advantage of their being thrown open when necessary, and particularly after the adjournment of Congress, thus filling the hall with a volume of pure air, and correcting whatever remains of the impurities created, (particularly when the galleries are crowded,) which may not have been drawn off by the mechanical means designed to control them.

Question. What improvement, if any, would you recommend in the present mode of lighting the halls at night?

Answer. The substitution of reflectors, as they would greatly lessen the number of distinct lights now used, and would be more economical, and equally, if not more, effective than the present mode.

Question. Is it your judgment that a very considerable loss of heat in the halls is produced by the present glass roofs?

Answer. It is, particularly during such weather as we had the present winter; for, from careful experiments, it has been found that 800 superficial feet of glass will cool down over 1,000 cubic feet of air as many degrees per minute as the internal temperature of the room exceeds the temperature of the external air.

Question. Is not the effect of a cold glass surface to throw down currents of cold air?

Answer. It is.

Question. Did you hear the statement of Dr. Antisell in reference to the upward movement of dust from the floor by the ascent of the air as introduced at present?

Answer. I did.

Question. Do you concur with him in his views?

Answer. I do.

Question. Would not the effect of Mr. Anderson's plan of removing the air below be to obviate this difficulty?

Answer. It would.

Question. Would the downward movement of the air tend to produce greater uniformity in the action of the air towards the floor?

Answer. All things being equal, there would be no difference between the unity of an ascending and descending current, for as Mr. Anderson's plan is to use one fan to supply the pure air, and another to draw off the impure, the air would be controlled by the power and harmonious action of the fans and not by its increased or diminished temperature, as it is at present, to a great degree.

Question. What effect, in your judgment, would the plan of bringing down the air have on the action of *sound* in the House?

Answer. My opinion is that the hearing would be improved.

Question. Would the air descending be broken by currents and of unequal temperature or would it be uniform throughout?

Answer. It would be nearly uniform—an inappreciable portion of it only affected near the floor and ceiling, provided the apertures in the ducts through which it enters the halls are of uniform size and numerous, *like a sieve*, and the apertures for the exit of the impure air alike numerous and uniform, and distributed close to the floor line.

Question. In your judgment would the air be less broken by currents than at present?

Answer. In my judgment it would, for as the air now enters the halls, the currents are manifest and numerous; and from the disparity in the dimen-

sions of the apertures through which it passes and the irregularity of their distribution, it cannot be otherwise.

Question. Is a fan the proper instrument for introducing and exhausting air?

Answer. It is so considered by architects generally, and I know of no better means.

Question. In your opinion could or could not this downward action of the air be controlled by a fan as proposed?

Answer. In my opinion it could.

Question. By this plan of Mr. Anderson would it or would it not be possible to introduce the air into the chamber above, and remove it below, or to reverse the movement?

Answer. It would.

Question. In reversing the action what changes would be necessary?

Answer. The location of the hydrating apparatus and of the heating apparatus.

BENJAMIN SEVERSON called and examined.

By the chairman:

Question. Will you state in what capacity you were employed in the construction of the Capitol wings, and what was done by you?

Answer. I was employed on the Capitol roofs and ceilings, in putting up the iron work, and generally as mechanical engineer. The work was performed under the direction of General Meigs. I was sent for in the first place to raise these iron roofs.

Question. On whose recommendation?

Answer. That of Stephen Colwell, Philadelphia.

Question. Did you put up the glass roof?

Answer. I put up the iron roof and then covered it with glass, copper, &c. I then had the supervision of putting up the ceilings.

Question. Will you state how the ceiling is made; whether it is capable of being removed and replaced readily; and if so, your reasons?

Answer. The ceiling is made of cast iron, in the form you see it. It is generally about a quarter of an inch thick, made in convenient pieces for handling, and put together with screwed bolts. I think there is not a rivet about the fastenings; I think it can be all unscrewed. That is my impression, and I inquired of the contractors, who told me the bolts were all screwed. It can be readily taken down, the plates laid aside and put back again when required. It will require nice care of course to replace the parts relatively, so that there shall be no mistake.

Question. Have you made estimates of the expense necessary to accomplish that purpose?

Answer. I have taken considerable pains to get at that reliably, and I have given my estimate in the form of a proposition. When I was asked the question at the last session I did not like to state until I could make a reliable estimate, which I have since done.

Question. Have you planned or designed buildings in your time?

Answer. That has been my business for the last twenty-five or thirty years.

Question. Have you designed churches, court-houses, &c.?

Answer. Yes, sir.

Question. Did you design the marine hospital at New Orleans for the government?

Answer. Yes, it was designed by me. After the government architect here had given me the number of rooms they wanted, I made the design, making the entire exterior of iron. I made the design of the roof of the custom-house and post office at Baltimore and several other buildings of that kind.

Question. What effect would the elevation of the wings as shown on Mr. Anderson's plan have upon the general appearance and architectural appearance of the building?

Answer. I do not pretend to be a finished architect, though I have some experience in these things. My opinion is that it will be decidedly favorable. I think the plan requires it. I think it would be a decided advantage to have such an elevation.

Question. What do you know of the settling of the new work of the Capitol on the west side of the two wings?

Answer. I cannot give the exact amount, but I know that in 1856 they were settled so much that we had to make an average of it in setting the iron work around the rooms. The building had settled less on the east side than on the west, there being a more perfect foundation on that side.

Question. What will be the effect of putting these proposed colonnades or porticoes on the west side of the wings?

Answer. The effect will be very injurious, for the reason that these porticoes are, as it were, detached from the old building, and will not have the advantage of its support. They will act with a leverage, as it were, being detached, and break their connexion. In my opinion it ought not to be done. That portion of the portico already up is yielding. I think you can see it on both wings, worse perhaps on the north than on the south wing.

Question. Could these spaces be finished with simple balustrades?

Answer. Yes, something of that sort; the architect could arrange it. I would not put up the columns as projected on the west side. I would dispense with the columns and entablatures both.

JACOB D. FORNEY called and examined.

By the chairman:

Question. Has the book now produced by you been kept by yourself or under your own supervision?

Answer. It has been kept under my own supervision.

Question. It contains, does it not, regular statements of various work, and particulars regarding the temperature of the hall of the House?

Answer. Yes, sir.

Question. Will you state where your observations of temperature were taken?

Answer. In the hall of the House of Representatives, three times a day, at 9, 12, and 3 o'clock. I took the average of the hall.

Question. How many thermometers?

Answer. There were six, I believe.

Question. And your statements show the average temperature by these thermometers?

Answer. Yes, sir.

Question. Do you believe these statements to be accurate?

Answer. Yes, sir.

Question. State what you have charge of in the Capitol.

Answer. I have charge of the heating and ventilating apparatus in the House of Representatives.

Question. How long have you been in charge of that apparatus?

Answer. Since February, 1864.

Question. Will you state your opinion as to the place of obtaining the air introduced, and its effect upon it?

Answer. In my opinion, in the summer time the temperature of the air is considerably raised by the rays of the sun beating upon the terrace and upon the sides of the building where the air is taken in. The air is taken from between the wings and the old Capitol, about the level of the terrace. I find that

the current of air thus taken into the south wing carries dirt and dust with it, and piles it up around the entrance against the sides of the building.

Question. Does the air pass a window on its way through?

Answer. There are two windows in the air chamber on the basement floor, and three on the upper floor.

Question. Do you find great irregularity in the thermometers at the same level in the hall?

Answer. Yes, sir, they vary on the average about three degrees on opposite sides of the hall.

Question. Have you taken observations in the galleries?

Answer. I have not.

Question. Nor in the space between the ceiling and roof.

Answer. No, sir.

Question. Have you charge of the roof?

Answer. Yes, sir.

Question. Can you state what inconveniences you find in connexion with the roof or upper part of the building?

Answer. During storms, or very heavy cloudy weather, it becomes very dark, and we have to light the ceiling at different times during the day. During rain-storms, it is almost impossible to hear anything in the House hall, on account of the sound from the copper roof. Last Sunday I noticed particularly, when the ice began to slide there was a tremendous sound, like distant artillery, which alarmed almost everybody in the house.

Question. State whether there is any leakage in the glass roof.

Answer. Yes, sir; it leaks probably in a dozen places.

Question. How do you remove the water?

Answer. We have to sponge it up.

Question. Does the space between the ceiling and roof become very much heated by the gas-lights?

Answer. Yes, sir; a man could not stand there ten minutes when the gas is lighted. I can stand considerable heat, but it drives me off.

Question. How many jets of light are there?

Answer. Over 1,200, I think.

Question. What is the effect of their being lighted on the temperature of the hall, if you have observed it?

Answer. In my opinion it increases the heat of the hall.

Question. Have you ever taken an observation of the heat on the floor before lighting the gas and afterwards?

Answer. I know it is much hotter after night in the hall, when the gas is lighted, than during the day. When the thermometer was at 80° or 83° during the day, I have seen it run up to 85° or 87° at night.

Question. What is the practical effect of the registers admitting air through the floor into the hall of the House?

Answer. They are used as much for spittoons as for admitting air, and there must be considerable nauseous effluvia arising from them from that cause. They are also used to sweep the dirt into.

Question. Are not the air chambers below very dirty?

Answer. We have found them very dirty.

Question. You have found them to contain "old sogers," and stumps of cigars, have you?

Answer. A plenty of them. Under the large registers we have found dried tobacco juice half an inch thick.

*February* 2, 1865.

The committee met.

Present: Messrs. Buckalew, Pike, and Smithers.

Examination of General M C. MEIGS.

By the chairman:

Question. State whether the work of Professor Reid is one of those books that you consider standard works on ventilation.

Answer. I think Professor Reid's work a very valuable one; but I think Professor Reid makes a great many mistakes. His works are very valuable, but I do not believe in all his conclusions by any means.

Question. What do you say as to the work of Professor Wyman?

Answer. Wyman's work I have read, but it is only a very general and rather superficial work, I think.

Question. Is it, in your judgment, a standard work on that subject?

Answer. I should not like to express an opinion about that. I do not recollect that I learned anything from it at all. I am not sure whether it contains errors or whether it is all right. There is a French book on heating, by Péelet, which is one of the most exhaustive works on the subject, and gives all the latest information, up to the time of its publication, on the subject of the art in France.

Question. What is your opinion of the present system of ventilating our halls?

Answer. I think it is the very best that can be devised.

Question. Equal to anything in the world?

Answer. I think it is the very best in the world. I have no doubt of it.

Question. Can you suggest any improvement in it?

Answer. None, if you have an intelligent man to regulate the heat.

Question. I am speaking of the plan.

Answer. No, sir, I cannot.

Question. In introducing air through the floors of the halls, do you consider the present plan of vertical ascent preferable to its introduction through the risers of the steps?

Answer. Yes, sir, and I can give you my reasons for it. In first arranging the details of the ventilation of the Senate chamber I introduced the air through the raisers of the steps, following Dr. Reid's ideas, making the openings as large as possible, so that the air should be diffused over the greatest area, and placing several thicknesses of wire gauze behind these openings so as to prevent a current of air as much as possible, and get as large a quantity of air as possible without its being felt between the person's legs. The hall was occupied by the senators very soon after this arrangement was completed; and before I had time to make any experiments and ascertain the result; I soon found a general complaint that the current of air was sensible, acting on the backs of the legs of the gentlemen who were seated on the various terraces on the floor, producing great discomfort, rheumatism, and such effects. That compelled me to change the whole thing, and let the air come in vertically. I tried that whole thing completely, and had to give it up.

Question. Did you also make a change by introducing air into the sides of the rooms?

Answer. At the sides of the rooms I placed shields before the openings so as to deflect the currents. People sitting on the sofas in the Senate chamber complained of the currents of air, and I sat there myself and found it so. I had not sufficiently realized the fact that warm air produces cold as well as cold air. It produces evaporation of moisture, and that produces cold.

Question. You speak from experiment?

Answer. I tried the thing and failed and had to give it up.

Question. Do you see any objection to placing a glass roof over the halls in connexion with the ventilation of the chambers?

Answer. There is a glass roof there now.

Question. Do you think there is any difficulty created in the ventilation by the glass roof?

Answer. No, sir; the glass roof has openings through which the air can escape. I left openings all around the edges of that glass roof, so that the air might escape generally through the ceiling as well as through the cornices.

Question. Would it not be an improvement if the glass roof were doubled?

Answer. It is already doubled. There is a glass roof and a glass ceiling. I do not see what would be gained by putting a third one in.

Question. Would it not prevent the loss of heat very much?

Answer. It would if the air in the room were still. Of course, the greater thickness you give to the roof the less heat would be lost by radiation. But you are now depending for the heat of the room upon the temperature of the air introduced. If you can bring in a certain quantity of air, of a certain temperature, every minute, and let it escape, it makes no difference whether the ceiling is thick or not.

By Mr. Pike:

Question. There are apertures enough to change the air, how often?

Answer. There are apertures enough, I think, to change it every five minutes. In the hall of the House, I think, 50,000 cubic feet of air can be supplied every minute. It is long since I looked at the figures, and I cannot trust my memory to speak with accuracy.

By the chairman:

Question. In your judgment, no exhausting power is required for ventilation?

Answer. No, sir; the ventilation is sufficient if the machinery is kept in order.

Question. State what objection exists to placing our halls at the sides of the wings?

Answer. When I took charge of the Capitol extension I found a plan being executed in which the hall of the House of Representatives was placed at the west end of the south wing, with windows on the three sides. I considered that there was danger of interference with debate in legislation by the effect of exterior noises which would come in through the windows. I noticed that in some public rooms in New York, churches, and other buildings which I had visited, this was a very serious inconvenience. Then the glass, cooled by contact with the external air, would produce currents of cold air within the room itself, which are sources of discomfort in the winter. It seems to me that members, occupied in the business of legislation, did not need, and would not have time to enjoy, any external prospect. I could secure a greater uniformity of temperature by placing the room in the centre of the building, removed from the external walls, and greater facility of ingress and egress by having corridors and galleries all around the hall. The waiting rooms, smoking rooms, committee rooms, &c., which are placed against the external walls, could thus be arranged so as to be of convenient access to members when not occupied in debate or legislation. All these considerations had their weight in inducing me to alter the plans and adopt those that have been executed.

Question. Would there not be another objection to a side exposure, from cross lights?

Answer. Yes; I had forgotten to mention that. I should add that one serious objection to windows on external walls is the disagreeable effect upon a speaker of having a bright light shining into his eyes when his face is turned toward any part of his audience. This, I think, was mentioned in the memoir

which I prepared on the subject at the time I took charge of the building and recommended the alteration of the plans.

Question. Is there any objection to obtaining the air, as at present, from the terraces?

Answer. I think not. It has been suggested, and I thought of it myself, to take the air from a higher point. It is a favorite idea to take the air for ventilation from a high tower, but I do not think that any real advantage would be gained from it. This terrace is clean, and it is eighty feet above the surface of the water. If you draw the air through a shaft leading up to the roof of the building you would be taking it at the level at which all foul air shafts discharge —at which all chimneys discharge their smoke—and you would be liable to draw and force into the interior of the building the very impurities which have been just expelled.

Question. State whether the present arrangement in ventilation is, throughout, your arrangement?

Answer. I cannot say that it is entirely my design or my work, because I had most skilful assistants.

Question. Is the present plan of ventilating the Capitol your arrangement?

Answer. Yes; it is my arrangement, with the assistance of men of skill.

By Mr. Smithers:

Question. You approved it?

Answer. Yes. I saw that an appropriation of $1,500 was made last year for some changes. What those changes were I do not know; nor do I know whether any alterations in my plan have been made. But, unless there have been changes within the last year or so, it is as I made it.

By the chairman:

Question. I ask you your judgment of the capacity of Mr. Walter on the subject of ventilation?

Answer. I would rather not answer that. I think Mr. Walter a very skilful architect, and a man of taste in his profession; but I think he has not even a smattering of science, and on all scientific questions his opinion is of no value.

THURSDAY, *February* 2, 1865.

*Re-examination of Benjamin Severson.*

By the chairman:

Question. State whether you have measured the extent of the glass roofs on both wings of the Capitol.

Answer. Yes.

Question. State the dimensions of the glass roof of the House and Senate, respectively.

Answer. The area of the glass surface of the House roof is 4,049½ square feet, and of the Senate 3,412½ square feet.

Question. It is a single roof?

Answer. Yes, a single thickness.

*Re-examination of Jacob D. Forney.*

By the chairman:

Question. State the capacity of the fan in use in the House for delivering air to the hall.

Answer. I never made an exact calculation of it, but, as a mechanic, I made

an estimate that the fan, running at the revolutions we run it now, delivers about 50,000 cubic feet of air per minute. We run it from 45 to 50 revolutions a minute.

Question. How much would it deliver if you used its power?

Answer. If the engines were properly constructed so that it could be run up, I could make it deliver double that quantity.

By Mr. Smithers:

Question. What can it deliver as now constructed?

Answer. I cannot run that engine with safety over 50 revolutions a minute, from the simple fact that the journals of the shaft are so small that they become heated and require to be cooled down.

By the chairman:

Question. There is another fan used for delivering air to the passages, corridors, and committee rooms?

Answer. Yes.

Question. That fan is less powerful?

Answer. Yes, it has not more than half the power.

Question. State whether there have been any of the air passages under the House closed, and, if so, for what object?

Answer. Last summer I found considerable complaint that there was not sufficient ventilation in the hall. After going under the floor of the hall and making an examination myself, I found a great many of the registers under the floor closed.

Question. For what purpose?

Answer. That I cannot say

Question. What do you say as to the plumbing generally, under the floors—has it been well executed—can you readily make repairs there?

Answer. There is a great difficulty in making repairs there, especially to the water pipes, gas pipes, &c. Being almost thoroughly imbedded in cement, it requires a cutting up of the tile-floors to get to the pipes.

Question. Have you charge of the roof and of the upper part of the building?

Answer. Yes.

Question. State whether storms beat in at the ventilators?

Answer. Several different times, to my knowledge, rain has come in through the ventilators to the ceiling, and through the ceiling to the floor of the House.

By Mr. Smithers:

Question. In any quantity?

Answer. It was considerable enough to wet the floor and the desks of members in several places. I had to place buckets on the ceiling to catch the drip, and also to sponge the water off the ceiling. I had also, several times, to place buckets on the floor of the hall to catch the water from the ceiling.

By the chairman:

Question. What is the consumption of gas for lighting the hall of the House of Representatives?

Answer. About 7,500 feet per hour.

Question. In order to light the hall, do you use the full power of the burners?

Answer. Yes, we give them the full pressure of the gas, just so that the burners shall not blow, as we call it—so that gas does not pass through without being consumed.

Question. Is not the effect of lighting your jets to produce a considerable amount of heat in the hall?

Answer. I have been always under the impression that it has that effect. I

have noticed particularly the thermometers rising at night, when the hall is lit, from two to five degrees.

Question. Is not the amount of heat produced in the space between the ceiling and the roof extremely great?

Answer. Yes, very great—so great that a man is not able to stand the heat there over ten minutes.

Question. After heating your halls in the morning, do you not reduce the power of the fan?

Answer. No, sir, but we reduce the pressure of steam. When the hall is properly heated by 10½ o'clock—say up to 68 degrees—I generally close off the main flow of steam and put on the exhaust. If, by 11½ o'clock, the hall is sufficiently warm I shut off the exhaust from the engine entirely and blow nothing but cold air into the hall for the remainder of the day. The brickwork underneath the floor of the hall becomes very warm from the amount of heat forced into it, and that keeps the air warm during the remainder of the day. I find no difficulty in heating the hall, but great difficulty in cooling it. That is the main difficulty with me.

Question. The effect of introducing an unusual amount of air would be to produce currents in the hall?

Answer. Yes, if the fan was driven at sufficient velocity.

By Mr. Smithers:

Question. Do you find it necessary to do that?

Answer. Through the summer I cannot get sufficient current through the registers.

Question. Owing to the want of apertures?

Answer. I cannot tell whether it is owing to the want of apertures or to the faulty construction of the air ducts.

By the chairman:

Question. Have you observed the difference in temperature in the summer between the air at the terrace and the air in the hall?

Answer. I can tell you by referring to my record here. I find that it runs about equal; that is, the temperature in the fan room and the temperature in the hall.

Question. I ask you of the difference of temperature between the terrace and the hall?

Answer. Taking it daily, there is a difference of about three degrees; that is, it is about three degrees cooler in the hall than in the fan room. But taking the average throughout, it runs about equal—the same temperature in the hall as outside.

Question. What degree of difference in temperature have you observed between the opposite sides of the hall?

Answer. About three degrees.

Question. Which side is the warmest?

Answer. The west side of the hall.

Question. Is that the side where the air is introduced?

Answer. Yes.

Question. Your record, as I understand, is a record of averages of temperature?

Answer. Yes.

Question. Of several thermometers in the hall?

Answer. Yes, of six thermometers.

*Average temperature by thermometers in the hall of the House of Representatives.*

*For week ending May* 15, 1864.

| | 12 o'clock. | 3 o'clock. |
|---|---|---|
| Monday | 77° | 79° |
| Tuesday | 77 | 81 |
| Wednesday | 77 | 79 |
| Thursday | 72 | 74 |
| Friday | 73 | 73 |
| Saturday | 73 | 74 |

*For week ending July* 3, 1864.

| | 12 o'clock. | 3 o'clock. |
|---|---|---|
| Monday | 87 | 87 |
| Tuesday | 77 | 78 |
| Wednesday | 76 | 79 |
| Thursday | 75 | 76 |
| Friday | 82 | 82 |
| Saturday | 85 | 84 |

*For week ending December* 18, 1864.

| | 12 o'clock. | 3 o'clock. |
|---|---|---|
| Monday | 70 | 73 |
| Tuesday | 70 | 74 |
| Wednesday | 70 | 75 |
| Thursday | 70 | 75 |
| Friday | 68 | 73 |
| Saturday | 72 | 73 |

*For week ending January* 22, 1865.

| | 12 o'clock. | 3 o'clock. |
|---|---|---|
| Monday | 70 | 71 |
| Tuesday | 70 | 72 |
| Wednesday | 70 | 72 |
| Thursday | 69 | 72 |
| Friday | 69 | 73 |
| Saturday | 68 | 72 |

*February* 6.

*John Kilby examined.*

By the chairman.

Question. How are you employed at the Capitol?

Answer. I am acting chief engineer of the Senate for heating and ventilating department.

Question. By whom employed?

Answer. By George T. Brown, Sergeant-at-arms of the Senate.

Question. What do you use in the warming pipes—hot water or steam?

Answer. Steam.

Question. Steam exclusively?

Answer. Yes, sir.

Question. Is there any arrangement for ejecting steam into the air between the fan and the Senate chamber?

Answer. There is none.

Question. But there is such an arrangement as to the air for the committee rooms and passages?

Answer. Yes, sir.

Question. But in practice you do not use steam for the rooms and passages?

Answer. No, sir. The reason is, if I use it to any large extent I make the furniture, glass, and walls reek with sweat. I found such effect caused by accidental breakage of steam in the coils. I think the effect of steam or hot air is to cause an unpleasant odar.

Question. What explanation do you give of the difference of temperature on opposite sides of the Senate chamber?

Answer. Some of the openings are closed on the north side. They can be opened.

Question. What pressure of steam do you use on the pipes?

Answer. I suppose an average pressure of 8 or 10 pounds to the square inch, say from 5 to 15 pounds. It depends upon temperature of external air used.

Dr. THOMAS ANTISELL re-examined.

By the chairman:

Question. Have you given personal examination to the ventilating arrangements of the Senate wing of the Capitol?

Answer. I have; the day before yesterday.

Question. What capital defects, if any, did you find in the ventilation?

Answer. That no hydration of the air was secured, and that the removal of the vitiated air above was incomplete.

Question. What do you say as to the heating arrangement?

Answer. The amount of heating surface of the pipes is ample, but if any of the compartments of pipes become defective their equivalent cannot be supplied. The arrangement for hydrating the air passage is defective and inoperative. The place from which the air is pumped or taken is objectionable, as liable to derive impurities both from the flagging and the walls of the building.

Question. Were you in the gallery of the Senate chamber, and what observation did you make there?

Answer. I was in the strangers' gallery and observed that the air had a strong smell of men and clothing; showing that the vitiated air was not fully removed.

Question. Did you then proceed to the air space above, next the roof?

Answer. Yes, sir; and we there found that the ventilation was accomplished by four air chimneys, 30 by 30 inches each, covered with a cap or cowl. This, Mr. Brown, the sergeant-at-arms, informed me was his arrangement, superseding the ridge ventilation of former plan. Now, when we contrast the capacity of those four air chimneys with the capacity of the supply passage, we find the former to have an area of twenty-five square feet, while the area of the supply shaft or passage is a little over thirty. There is, therefore, a want of equivalent capacity. Then the current in the supply shaft is at the rate of between six and seven miles per hour, while that of the air escaping from the air shafts of the roof does not amount to four miles per hour. There is, therefore, a deficient capacity equal to one-sixth, and a deficient movement equal to one-third.

Question. What do you say as to the roof?

Answer. The materials of the roof—glass and metal—are very objectionable if the air space below is to be used as at present. The glass warms it unduly in summer, and the metal cools it unduly in winter. If the air is to be brought into the chamber from above, (as proposed by Mr. Anderson's plan,) there should be air ducts over the ceiling, well protected from external heat and cold.

Question. Would an inner roof, counter-ceiled or covered with a non-conducting material, exclude the noise of storms from the chamber?

Answer. The double-roof itself, with an air space between, would be one of the best arrangements for the non-conduction of sound.

Question. Would the filling in or covering the inner roof, as suggested, have

additional effect in excluding the influence of the external atmosphere upon the air between the inner roof and the ceiling?

Answer. Yes, certainly.

Question. For filling in or covering the inner roof, is broken pumice-stone, with liquid cement, a proper material?

Answer. I know nothing better; combining, as it does, lightness, solidity, and incombustibility.

Question. What is the effect of the hot air under the roof?

Answer. Its accumulation there, without sufficient means of escape, is to back-up against the out-going currents from the Senate chamber and prevent their escape.

Question. What do you say as to the use of fewer lights over the ceiling, *with reflectors?*

Answer. There is advantage in many lights in producing softness and lighter shadows, but as at present arranged they are an obstruction to ventilation. Fewer lights, with reflectors, might be equally satisfactory, and aid the ventilation vastly.

Question. Would not the descent of the air in the halls obviate the present defect of dust rising in the room from the floors?

Answer. Certainly.

Question. In changing the course of the air in the halls from an upward to a downward movement, what effect would be produced upon the air near the floor, as to uniformity of movement and temperature?

Answer. The temperature would be more uniform, and as to movement, that would depend upon the force of the exhausting fan.

Question. Would there be an advantage in chimnies with the proposed lights as shown in the new plans?

Answer. Yes, sir, by removing the immediate products of combustion from the lights, and by ventilating the air space above the ceiling.

Question. Would there be less heat thrown down into the halls from the lights than at present?

Answer. Certainly, by the process of removal of products of combustion and the heated air.

Question. Would there be a saving of heat by the change?

Answer. I think so.

Question. What do you say as to the feasibility and success of Mr. Anderson's whole plan, as compared with the present arrangement?

Answer. It would be much more effective than the present plan, and feasible in its details.

Question. Can the plan be exactly reversed as to direction of the movement of the air, if desired hereafter, assuming that it should now be adopted?

Answer. Certainly, with little expense and alteration.

Question. What credit is to be attached to Professor Wyman's work on ventilation?

Answer. It is a very valuable and reliable work on the subject. We would refer to it for principles and rules, rather than for practical details.

The witness adds:

The present means of escape in the apertures in the Senate ceiling, are not in my opinion sufficiently extensive; and, if Mr. Anderson's plan should be adopted, would not be sufficient for the ingress of the air. Placing wire gauze screens in the parallelogram spaces along the sides of the ceiling would afford increased facilities for the entrance of the air.

With regard to admitting the air at the sides of the Senate chamber, and its cooling effect upon individuals, (which have been mentioned,) such effect is not so much due to the velocity of the air as to its aridity. When I stood in the air passage below, with the air blowing at full velocity, the effect was chilliness of the surface, the air being at 70° with an out-door moisture of 30°.

FEBRUARY 14, 1865.

Dr. CHARLES M. WETHERILL examined.

By the chairman:

Question. Have you taken the dew point in the Senate chamber this winter with instruments?

Answer. Yes, on two occasions, January 24 and February 9. The first day the observations were as follows:

| | Dry bulb. | Wet bulb | Relative humidity. |
|---|---|---|---|
| In ladies' gallery, near reporters' gallery, $2\frac{1}{4}$ p. m. | 72° | 55° | 27° |
| Do., near diplomatic gallery, 2 40 p. m. | 72.3 | 55.4 | 27 |
| External air entering ventilating fan, 3 p. m. | 29.8 | 25.2 | 56 |
| In post office, near the window, $12\frac{1}{4}$ p. m. | 61.9 | 51.8 | 46 |
| Do., on mantel-piece, same time | 70.2 | 55 | 32 |

Question. What is meant by "relative humidity?"

Answer. It means the amount of moisture present, with reference to saturation taken as 100.

Question. What observations did you make on February 9?

Answer. The air entering the fan (the fan making 45 revolutions per minute) had a temperature of 30.6°, and the relative humidity was 55°. This was at $2\frac{1}{2}$ p. m. In the southeast corner of Senate chamber, on level with desks, at $3\frac{1}{2}$ p. m., the temperature was 70.9°, and the relative humidity 20. In diplomatic gallery, at 4 o'clock, the temperature was 68°, and its relative humidity 21. In the illuminating loft, or air space between the ceiling and roof, in northwest corner, at 4.30 p. m., the temperature was 64°, and its relative humidity 27.

Question. What is the average relative humidity of atmospheric air?

Answer. According to the results of the meteorological observations made at the Smithsonian Institution, published in executive documents for 1st session 36th Congress, the mean relative humidity for Washington in June, 1859, was, for 7 a. m., 75; for 2 p. m., 56; for 9 p. m, 76. The minimum results for the same hours, during same month, were 42, 31, and 51. For month of February, for same year, the mean relative humidity was, at 7 a. m., 80; at 2 p. m. 62; at 9 p. m., 71; and the minimum for those hours was 36, 34, and 33. H. E. Roscoe states that in the House of Lords the air is pleasant to breathe when its relative humidity ranges between 55 and 82. He also states that the mean annual relative humidity for England is about 75.

## MR. ANDERSON'S STATEMENT.

[At the request of the committee, Mr. Anderson states the following particulars of his professional career.]

I am 63 years of age; have been studying and practicing my profession exclusively and without intermission since the year 1819; was educated at the Fermoy college, in class with Dr. Shelton Mackenzie, of the Philadelphia Press; studied classic architecture under Messrs. Harrison and Hargrave as an apprentice for five years; afterwards studied Gothic, baronial, ecclesiastical, and monumental architecture under Messrs. Pain, of London, while architects to the ecclesiastical commission for Ireland. While under their instruction, I superintended the construction of Emly cathedral, and had considerable experience in heating and ventilating ecclesiastical edifices, with a view to good ventilation and acoustics. I commenced practice on my own account in 1829, by competing for and winning the premium for the approved design of the great Catholic university for Ireland, at Thurles, near the ancient city of Cashel.

While conducting the construction of that building, I designed and erected Spring House, an extensive mansion for John Low, esq.; Bansha castle for the lord lieutenant of the county; Castle Cray for G. L. Bennet, esq.; and the Episcopal church and national school building in the town of Tipperary; I also brought water into that town, and built the Savings bank. I was employed on the staff of Alexander Nimmo, the engineer-in-chief to the British government, and was employed with his two brothers-in-law, McGill and Simpson, in the construction of the works on the Shannon, and the Limerick bridge, the greatest work of the kind in Britain. Afterwards conducted the erection of the bridge across the river Tay, at Strad-bally, and the bridge across an arm of the sea at Ballyvoile; also the water battery at Duncannon fort, which guards the river Shure, where General Slade was in command. I superintended the erection of the new county jail, Waterford, and the jail and court-house in Middleton, county of Cork. I won the government premium for the classification prison for Ireland, which brought me into notice. I was permanently employed as architect and chief engineer on the estates of the present Earl of Kingston, and built a great deal for him. Also built a mansion for Lord Massey. I designed and superintended the building of Ash Hill castle, for Eyer Evans, esq.; Castle Ivers, for Robert Ivers, esq., and Farney castle, for Captain Armstrong. I conducted the buildings of the poor law commission, in the counties of Cork and Tipperary. I was extensively employed on the estates of the Earl of Bantry, Sir George Coldthurst, M. P., Sir William Wrixen Beacher, and Sir Robert Abercromby.

I designed and built Anner castle for the Rev. Nicholas Herbert Mandeville, cousin to the Marquis of Waterford; also, Jenkinstown castle, for the sister of the Marquis of Shrewsbury; and Milltown house, for George Gubbins. I made some beautiful buildings for J. Power, M. P., of Gurteen, step-son to the Hon. R. L. Shiel, master of the British mint; also for his brother, Sir John Power, of Kilfane. I also remodelled Tara hall for Lord Tara, and built the Deer Park house, near Cashel, for Hon. John Hare; Bantry house, for J. O'Connell, and the Presbyterian church in the city of Kilkenny. I changed the course of the river Blackwater for Mr. Cliff, of Wexford, and designed Augentine house for Thomas Brown, esq., cousin to Brown the banker, of Baltimore; with many other extensive works, occupying a successful practice of twenty years, until the plague and famine of '48, when I left my native country to join my numerous relatives, long settled in the United States. In 1849 I arrived in New York. I had an introduction to Judge Edmunds, of the supreme court, inspector general of prisons, who induced me to compete for a premium advertised by the ten governors for the best plan for the penitentiary workhouse on Blackwell's Island. I presented a design and plan in six weeks after my arrival, and won the premium, with eighteen distinguished architects my competitors. In a few months after won the advertised premium for the Baltimore house of refuge for juvenile delinquents; also, the New York new city hospital, and for the emigrant hospital in New York; also, for different churches—Dr. Sunderland's on 4½-street, Washington, and the great Catholic cathedral at St. John's, New Brunswick. I also obtained the advertised premium for the approved plans for the University of the South, to be erected on Cumberland mountain, in Tennessee, (just before the war commenced,) competing plans being presented from every city of note in this country, north and south. Among my competitors were General Rosecrans and Mr. Rogers, supervising architect of the treasury department. In 1850 I presented my first design for the Capitol extension, in answer to a public advertisement, which design was partly used, and which obtained an equal proportion of the advertised premium, with four others—Mr. Walter not being among them, as his plans were marked rejected, and were quite different from any of the plans afterwards used.

In 1853 I furnished to General Meigs, for the use of the government, my

second or modified design, prepared in 1851 at the suggestion of President Fillmore, with verbal and printed instructions, detailing the system of ventilation which I recommended. These papers and explanations were used by General Meigs in his report, which was endorsed by Professors Bache and Henry. I acted as General Morton's chief civil engineer on the aqueduct works, and designed a new jail, penitentiary, and house of correction for juvenile delinquents for the District of Columbia. I also designed plans for new law court buildings and post office for the city of New York, and lately furnished the Spanish government, through their Washington minister, the plans for the great national exhibition building to be erected at Madrid. I completed two works on architecture, one published in Europe, "The Ancient Church Edifices of England," the other, "Anderson's American Villa Architecture," published in New York in 1853. I have also been professor of architecture and civil engineering in two different colleges, one in Europe and one in America. When an apprentice I accompanied Mr. Hargrave on a professional tour through the principal cities in Europe and investigated their principal buildings. It was in the French theatres, in old Drury lane theatre, and in St. Paul's cathedral that I observed the true system or plan for conveying sound and avoiding reverberations. I had personal knowledge of the failure of Dr. Reid's system for the ventilation of the new houses of Parliament and the Millbank penitentiary. His chimney plan has been avoided in late public structures in England and the fan substituted.

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A.

*Temperature of the Senate Chamber.*

| | On the floor. | | Adjournment of the Senate. | In the gallery. | | Adjournment of the Senate. |
|---|---|---|---|---|---|---|
| | 12 m. | 3 p. m. | | 12 m. | 3 p. m. | |
| 1865. | ° | ° | ° | ° | ° | |
| Jan. 18 | 69 | 70½ | 3½ o'clock, 71½ | 78 | 73 | 3 o'clock, 74 degrees. |
| 19 | 69½ | 69 | 4 " 70 | 81 | 73 | 4 " 72 " |
| 23 | 70 | 71 | 4¼ " 69 | 78 | 72 | 4¼ " 70¾ " |
| 24 | 69½ | 70 | 4½ " 70½ | 78 | 72 | 4½ " 71 " |
| 25 | 69 | 70½ | 4.5 " 71 | 82 | 75 | 4.5 " 74½ " |
| 26 | 69½ | 72 | 4.20 " 70 | 82 | 73½ | 4.20 " 72 " |
| 27 | 68½ | 71 | 4½ " 71½ | 81 | 74 | 4½ " 71½ " |
| 28 | 66½ | 70 | 4.25 " 70½ | 79½ | 73 | 4.25 " 72 " |

B.

*Temperature of the Senate Chamber.*

| | 12 o'clock, m. | 3 o'clock, p. m. | Adjourned. |
|---|---|---|---|
| 1865. | | | |
| Jan. 18 | 70½ degrees............ | 72 degrees............ | 3½ o'clock, 72½ degrees. |
| 19 | 71 " ............ | 71½ " ............ | 4 " 73 " |
| 23 | 72 " ............ | 72 " ............ | 4½ " 72 " |
| 24 | 72 " ............ | 73 " ............ | 4½ " 72 " |
| 25 | 72 " ............ | 73 " ............ | 4.5 " 73½ " |
| 26 | 72 " ............ | 73 " ............ | 4.20 " 72½ " |
| 27 | 70 " ............ | 74 " ............ | 4½ " 73 " |
| 28 | 68 " ............ | 72 " ............ | 4.25 " 72½ " |

## MOISTURE OF AIR.

Dr. Youmans represents the capacity of air for moisture by a diagram. Assuming the capacity of air for moisture at 100 degrees of temperature to be represented by the number 100, then its capacity at 60 degrees would be about 31, and at 32 degrees 12½. (Sec. 308.)

Porter's chemistry represents the capacity of a cubic yard of air for moisture at different temperatures to be as follows:

| | | | | |
|---|---|---|---|---|
| At 50 degrees, | ½ cubic inch | vapor of water. | | |
| 75 | do | 1 | do | do. |
| 100 | do | 2 | do | do. |

The American Agriculturist gives the following statement as to the absorbing power of air in a room 12 by 15 by 9 feet, containing 1,620 cubic feet, regard being had to temperatnre:

| | | | | |
|---|---|---|---|---|
| At 32 degrees, | absorption | 3,807 grs. = ½ pt. | vapor of water. | |
| 50 | do | do | 6,869 grs. = 1 pt. | do. |
| 70 | do | do | 12,863 grs. = 2 pts. | do. |
| 100 | do | do | 30,975 grs. = 5 pts. | do. |

The capacity of one cubic foot of air for moisture, by weight, at differen tempertures is as follows:

| | | | |
|---|---|---|---|
| 0° zero, | 18 grains | vapor of water. | |
| 32 degrees, | 2.35 | do | do. |
| 40 do | 3.06 | do | do. |
| 50 do | 4.24 | do | do. |
| 60 do | 5.82 | do | do. |
| 70 do | 7.94 | do | do. |
| 80 do | 10.73 | do | do. |
| 90 do | 14.38 | do | do. |
| 100 do | 19.12 | do | do. |

| | | | |
|---|---|---|---|
| Air at 32 degrees | will contain | $\frac{1}{160}$ | of its weight of vapor. |
| 59 | do | $\frac{1}{80}$ | do. |
| 86 | do | $\frac{1}{40}$ | do. |
| 113 | do | $\frac{1}{20}$ | do. |
| 140 | do | $\frac{1}{10}$ | do. |

(Youmans, sec. 286.)

JOHN. A. ROWLAND.

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NEW YORK CITY HOSPITAL, BROADWAY.

SIR: In answer to your inquiries, I have the pleasure to state that there are upright air shafts, each about four feet in the clear, erected at each end of a longitudinal horizontal passage or tunnel under the basement floor, through which the fresh air is supplied. This air is admitted into a series of small air chambers, through valves 10 by 14, which are connected with the main fresh air tunnel. In these small air chambers the air is rarefied by means of steam pipes in coils, and from these small air chambers the rarefied air ascends to the different wards through flues in the walls opening into the wards, by means of the registers placed about two feet from the floors.

The ventilating flues, or flues for taking off the impure air, are in the side walls of the different wards, situated close to the floors, and also about ten inches from the ceilings, which flues are connected with the foul air chambers at the top of the building, into which they discharge their foul air, the chambers being

kept constantly heated by a coil of steam pipe placed in the top, and immediately under these openings above the roof.

This is a self-acting system, using steam only without the use of a fan.

B. F. McALHATTEN,
107½ *Avenue D, New York.*

Hon. CHAS. R. BUCKALEW.

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ARCHITECT'S OFFICE, 54 EXCHANGE PLACE,
*New York, December* 5, 1864.

SIR: In compliance with your desire, I have much pleasure in furnishing you with the information you require, as to the system which has been adopted for ventilating the new emigrant hospital, now in course of erection on Ward's island.

1st. The building is under the control of the commissioners of emigration.

2d. The air which is supplied to the different wards is brought through an elevated shaft, placed at some distance from the building.

3d. The air is collected in an air-chamber, under the level of the basement floor, from whence it is forced, by the action of a fan wheel, through large brick ducts, which run under each building; from thence it is taken, through hollow iron shafts, to the different wards in controllable quantities.

4th. The impure air is withdrawn by means of flues in the walls, situated in the piers behind the patients' beds, in each ward.

5th. This impure air is attached to the great upper foul-air shaft, which discharges its contents at a height over the roofs. The fan is only used for the purpose of securing a proper quantity of pure air at all seasons to the wards, independent of the windows.

Very respectfully, your obedient servant,

JOHN W. RITCH.

Hon. CHAS. R. BUCKALEW,
*United States Senate.*

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RESOLUTION.

IN THE SENATE OF THE UNITED STATES,
*May* 9, 1864.

*Resolved by the Senate, (the House of Representatives concurring,)* That a joint select committee, to consist of three members on the part of each House, be appointed by the respective presiding officers, to examine into the present con dition of the Senate chamber and hall of the House of Representatives, as regards the lighting, heating, ventilation, and hearing, and the defects and disadvantages existing in the same. That the said committee obtain from Charles F. Anderson, architect, a statement of the principles upon which he proposes to regulate those particulars, with a view to their improvement, so as to secure the better adaptation of those halls to the purposes of legislation, and the preservation of the health of those occupying them; and that the committee also obtain a statement or estimate of the expense that will attend the necessary alterations, and the probable time that will be required for making them; and the said committee shall be authorized to report, by bill or otherwise, at the present or next regular session of Congress.

Attest:

J. W. FORNEY,
*Secretary.*

IN THE HOUSE OF REPRESENTATIVES U. S.,
*May* 10, 1864.

*Resolved,* That the House of Representatives concur in the foregoing resolution of the Senate, providing for the appointment of a joint select committee to examine into the present condition of the Senate chamber and hall of the House of Representatives.

*Ordered,* That Mr. Morrill, Mr. Smithers, and Mr. English be appointed the said committee on the part of the House.

Attest: EWD. McPHERSON, *Clerk.*

IN THE SENATE OF THE UNITED STATES,
*May* 10, 1865.

The President *pro tempore* appointed Mr. Buckalew, Mr. Howard, and Mr. Henderson the committee on the part of the Senate, under the foregoing resolution.

Attest: J. W. FORNEY,
*Secretary.*

IN THE HOUSE OF REPRESENTATIVES,
*January* 5, 1865.

The Speaker appointed Mr. Pike a member of the joint committee (select) on ventilation, in place of Mr. Morrill, excused.

Attest: EDWARD McPHERSON,
*Clerk.*
By CLINTON LLOYD,
*Chief Clerk.*

*Appropriation in second section of miscellaneous appropriation act of July 2, 1864. Laws of* 1863–'4, *page* 362.

For plans and detailed drawings for proposed changes in the Capitol wings, to secure improvements in the ventilation, heating, and acoustics of the halls of Congress, the sum of fifteen hundred dollars, or so much thereof as may be necessary; the said outlay to be authorized and approved by the joint select committee of the two Houses upon the ventilation &c., of said halls, and to be paid out of the aforesaid appropriation for the Capitol extension.

## INDEX.


Anderson, Charles F., report .......... 15
Estimates .......... 24
Testimony .......... 40
Statement .......... 57
Antisell, Dr. Thomas, testimony .......... 36, 55
Bache, Prof. A. D .......... 24
Bassett, Isaac, testimony .......... 43
Tables of Senate chamber temperature .......... 59
Cluskey, Charles B., testimony .......... 44
Forney, Jacob D., testimony .......... 47, 51
Tables of House hall temperature .......... 54
Forsyth, William, testimony .......... 42
Henry, Prof. Joseph .......... 24
Kilby, John, testimony .......... 54
McAlhattan, B. F., letter .......... 60
Meigs, General M. C., testimony .......... 49
Old report .......... 22
Notes on acoustics .......... 23
Moffatt, Captain Richard R., testimony .......... 42
Resolution for appointment of committee .......... 61
Ritch, John W., letter .......... 61
Rowland, Dr. John A., testimony .......... 43
Authorities cited by .......... 60
Severson, Benjamin, testimony .......... 46, 51
Estimates and proposals .......... 25
Shedd & Edson, report on ventilation .......... 28
Wetherill, Dr. Charles M., testimony .......... 57

[FOR THE USE OF MEMBERS.]

# Royal Institution of Great Britain.

1851.

WEEKLY EVENING MEETING,

Friday, May 23.

THE REV. JOHN BARLOW, M.A., F.R.S., Secretary R. I.
in the Chair.

WILLIAM HOSKING, ESQ,

PROFESSOR OF ARCHITECTURE AND OF ENGINEERING CONSTRUCTIONS AT
KING'S COLLEGE, LONDON.

## *On Ventilation by the Parlour Fire.*

THE term Ventilation does not strictly imply what we intend by its use in reference to Buildings used as dwelling-houses, or otherwise for the occupation of breathing creatures. To ventilate is defined "to fan with wind;" but one of the main objects for which houses, and other enclosed buildings, are made is shelter *from* the wind, Inasmuch, however, as the wind is but air in motion, and we can only live in air, air may not be shut out of our houses, though, for comfort's sake, we refuse to admit it in the active state of wind. But in doing this — in shutting out the wind,— we are apt to put ourselves upon a short allowance of air, and to eke out the short allowance by using the same air over and over again.

There is a broad line of distinction, indeed, to be drawn between in-door and out-door ventilation; for although the principles upon which nature proceeds are the same, the operation is influenced by the circumstances under which the process may be carried on. Whether it be on the hill-side, open to the winds of heaven, or in a close room from which all draught of air is excluded, the expired breath, as it leaves the nostrils heated by the fire in the lungs, rises, or seeks to rise, above their level, and may not be again inhaled. Out of doors the cooler or less heated air of the lower level presents itself for respiration unaffected by the spent exhaled air, but in a close apartment the whole body of included air must soon be affected by whatever process any portion of it may have undergone. The process by which Nature carries off spent air, purifies, and returns it uncontaminated, is thus checked by the circumstances under which we place ourselves within-doors. All our devices for shelter from the weather, and for domestic convenience and comfort, tend to prevent the process provided by Nature from taking effect according to the intention in that respect of the Creator. We not only confine

ourselves, indeed, and pen up air in low and close rooms, but we introduce fire by which to warm the enclosed air; wanting light within our dwellings when daylight fails, we introduce another sharer in the pent-up air of our rooms, being fire indeed, in another form, but generally under such circumstances, that it not only abstracts from the quantity, but injures the quality of what may remain. But fire, whether in the animal system, in the grate, or in the lamp, cannot long endure the imagined limitation of air. There must be access of air — of vital air — by some channel or other, or the fire will go out.

An open fire in the grate must however have a vent for some of its results, or it will be so disagreeable a companion that its presence could not be endured, even as long as the most limited quantity of air would last; and the fire will compel the descent of air by the vent commonly supplied under the name of a flue — a chimney flue — to render its presence tolerable in a closed room, if a supply be not otherwise obtainable. But as the outer air at the higher level of the top of a chimney, because of the rarity of the air in and above the flue, responds to the demand of the fire less easily than the lower air, or that at and about the level of the fire; and the lower air, or air at the lower levels, forces its way in, therefore, by any opening it can find or make — through the joints of the flooring-boards and under the skirtings — the supply passing first up or down the hollow, lathed and plastered partitions, sometimes even up from the drains; and through the joints under and about the doors and windows. If these channels do not exist, as they may not when the joiners' work and the plastering are good, or when the open joints referred to are stopped up by any means, the fire smokes, and every known means of curing the chimney failing, means are sought of obtaining heat without the offending fire. Ventilation is not thought of yet.

The open fire may be made to give place to the close stove or to hot air pipes, to hot-water pipes or to steam pipes—which make hot the air about them in a close room without causing draughts. But the warmth obtained in pipes is costly under any circumstances. Air does not take up heat freely, unless it be driven and made to pass freely over the heated surface; and there being little or no consumption of air, and consequently little or no draught in connexion with heated bodies, such as close stoves and hot pipes, the heat from them is not freely diffused, and is not wholesome. There is with all the expense no ventilation.

Stoves and hot pipes are, moreover, exceedingly dangerous inmates in respect of fire. Such things are the most frequent causes, directly or indirectly, of fires in buildings. Placed upon, or laid among or about the timbers and other wood-work of hollow floors, and hollow partitions, and in houses with wooden stairs, more conflagrations are occasioned by hot pipes and stoves, than by any thing else, and perhaps more than by all other things together.

Open stoves with in-draught of air warmed by being drawn quickly (when it is drawn quickly) over heated surfaces may be

made part of a system of safe and wholesome in-door ventilation; but to be perfect there must be also out-draught with *power* to compel the exit of spent or otherwise unwholesome air. But the arrangements for and connected with such stoves are special and therefore costly, unless the buildings in which they may be employed have been adapted in building to receive them. An in-draught stove may however be applied with great advantage as it regards the general warmth and ventilation, in the lowest story of any house, if there be compelled out-draught at the highest level to which it will naturally direct itself if it be not retained, so that the in-draughted air, tempered as it enters, may be drawn out as it becomes spent, or otherwise contaminated.

But this must be considered in all endeavours to effect in-door ventilation, or the endeavour will fail. *The air must be acted upon, and not be left, or be expected, to act of itself, and to pass in or out as may be desired merely because ways of ingress and egress are made for it.* Make a fire in a room, or apply an air-pump to the room, and the outer air will respond to the power exerted by either by any course that may be open to it, and supply the place of that which may be consumed or ejected; but open a window in an otherwise close room and no air will enter; no air can enter, indeed, unless force be applied as with a bellows, whereby as much may be driven out as is driven in, with the effect only of diluting not of purifying. Even at that short season of the year in which windows may be freely opened, unless windows are so placed as to admit of the processes of out-door ventilation being carried on through them by a thorough draught from low levels to high levels, open windows are not sufficient to effect thorough in-door ventilation. There must for this purpose be in every room a way by which a draught can be obtained, and this draught must take effect upon the most impure air of the room, which is that of the highest level. The chimney opening may supply a way at a low level, and a draught may be established between it and the window, but the air removed from the room by such a draught is not necessarily the spent or foul air. But make an opening into the chimney flue near the highest level in the room, that is to say, as near as may be to the ceiling, and if a draught be established between the window and the flue by this opening the ventilation is complete; that is to say again, if there be draught enough in the chimney flue from any cause to induce an up-current through it, or if there be motion of the external air to drive the air in at the window and force an up-current through the flue.

Windows may not be put open in the long enduring colder season, however, and for the same reason in-draughts of the outer air by any other channel are offensive and injurious. To open a door for the sake of air is but a modification of opening a window, and, if the door be an internal one, with the effect of admitting already enclosed, and, probably, contaminated air. Means of efficient in-

door ventilation must therefore, be independent of windows and doors; and the means should be such as will lead to a result at once wholesome and agreeable.

Many plans have been suggested, and some have been carried into effect, of warming air, and then forcing it into or drawing it through buildings, and, in the process of doing so, removing the foul, or spent air from the apartments to which it may be applied. Some of these plans are more and some are less available to wholesome and agreeable in-door ventilation, but even the best are rather adapted to large apartments, such as those of Hospitals, Churches, Theatres, and Assembly-Rooms, than to private dwelling houses in which the rooms are small and labour and cost are to be economised.

Plans have been proposed, too, for the economical ventilation of dwelling houses; but they seem to be all in a greater or less degree imperfect. Ways of access are provided in some cases for the outer air directly to the fire in every apartment, to feed the fire, and indirectly to ventilate the room; way of egress in addition to the chimney opening and the chimney flue being sometimes provided for the spent air of the room; sometimes, indeed, as before indicated, by an opening into the chimney flue near the ceiling. A direct in-draught of cold air is not agreeable, and it may be pernicious, but if the outer air become warm in its way to the inmates of the room, the objection to its directness ceases. If however the warmth is imparted to it with foulness, the process does not fulfil the condition as to wholesomeness, and this is the case, ~~done~~ when the outer air is admitted at or near to the ceiling to take up warmth from the spent and heated atmosphere of the higher levels. Having undergone this process, it is not the fresh air that comes warmed to the inmates, but a mixture of fresh and foul air that cannot be agreeable to any inmate conscious of the nature of the compound.

The endeavour on the present occasion is to show how the familiar fire of an apartment may be made to fulfil all the conditions necessary to obtain in-door ventilation, to the extent at least of the apartment in which the fire may be maintained, and while it is maintained.

A fire in an ordinary grate establishes a draught in the flue over it with power according to its own intensity, and it acts with the same effect, at least, upon the air within its reach, for the means which enable it to establish and keep up the draught in the flue. The fire necessarily heats the grate in which it is kept up, and the materials of which grates are composed being necessarily incombustible, and being also ready recipients and conductors of heat, they will impart heat to whatever may be brought into contact with them.

It is supposed that the case containing the body of the grate is set on an iron or stone hearth in the chimney recess, free of the sides and back except as to the joints in front. Let all communication between the chamber so formed about the back and sides of the grate and the chimney flue be shut off by an iron plate, open only

for the register flap or valve over the fire itself. External air is to be admitted to the closed chambers thus obtained about the grate by a tube or channel leading through the nearest and most convenient outer wall of the building and between the joists of the floor of the room, to and under the outer hearth or slab before the fire, and so to and under the back hearth in which sufficient holes may be made to allow the air entering by the tube or channel to rise into the chamber about the fire-box or grate. Openings taking any form that may be agreeable are to be made through the cheeks of the grate into the air-chamber at the level of the hearth. In this manner will be provided a free inlet for the outer air to the fire-place and to the fire, and of the facility so provided the fire will readily avail itself to the abolition of all illicit draughts. But the air in passing through the air chamber in its way to the fire which draws it, is drawn over the heated surfaces of the grate and it thus becomes warmed, and in that condition it reaches the apartment.

An upright metal plate set up behind the openings through cheeks of the grate, but clear of them, will bend the current of warmed air in its passage through the inlet holes, and thus compel the fire to allow what is not necessary to it to pass into the room; and if the opening over the fire to the flue be reduced to the real want of the fire, the consumption of air by the fire will not be so great as may be supposed, and there will remain a supply of tempered air waiting only an inducement to enter for the use of the inmates of the apartment. An opening directly from the room into the flue upon which the fire is acting with a draught more or less strong, at a high level in the room, will afford this inducement; it will allow the draught in the flue to act upon the heated and spent air under the ceiling, and draw it off; and in doing so will induce a flow of the fresh and tempered air from about the body of the grate into the room.

The mode thus indicated of increasing the effect of the familiar fire, and making it subservient to the important function of free and wholesome ventilation, is not to be taken as a mere suggestion, and now for the first time made. It has been in effective operation for six or seven years, and is found to answer well with the simple appliances referred to. But it is the mode and the principle of action that it is desired to recommend, and not the appliances, since persons more skilled in mechanical contrivances than the author professes to be, may probably be able to devise others better adapted to the purpose.*

The mode referred to of warming and ventilating apartments by their own fires is most easy of application, and in houses of all kinds, great and small, old and new, and as the warmth derived from the fire in any case, comes directly by the in-draughted air, as well as by radiation of heat into the air of the apartment, fuel is economized. If the register flap be made to open and shut, by any

* The appliances used by Mr. Hosking, will be found more fully described in his "Healthy Homes" published by Mr. Murray.

means which give easy command over it, so that it may be opened more or less according to the occasion, and this be attended to, the economy will be assured, for it is quite unnecessary to leave the same space open over the fire after the steam and smoke arising from fresh fuel have been thrown off, as may be necessary immediately after coaling. The opening by the register valve into the flue may be reduced when the smoke has been thrown off, so as to check the draught of air through the fire, and greatly to increase the draught by the upper opening into the flue, to the advantage of the ventilation and to the saving of fuel, while the heat from the incandescent fuel will be thereby rather increased than diminished.

Moreover the system being applicable in the cottage of the labourer, as fully and as easily as in the better appointed dwellings of those who need not economize so closely as labouring people are obliged to economize, the warmed air about the grate in a lower room may be conveyed directly from the air-chamber about the grate by a metal, or pot pipe, up the chimney flue, and be delivered in any upper room next to the same flue and requiring warmth and ventilation, the process of ventilation applied to the lower room being applicable to the upper room also.

The indicated means by which winter ventilation is obtained are not of course equally efficient in summer, for the draught of the fire is wanting; but the inlet at the low level for fresh air, and the outlet for the spent air at the upper level continuing always open, the heat which the flue will in most cases retain through the summer aided by that of the sun's rays upon the chimney top, secures a certain amount of up-draught, which is not without its effect upon the in-draught by the lower inlet even when windows and doors are shut.

While it is obvious that the air drawn into any house for the purpose of in-door ventilation need not be other than that which would enter by the windows of the same house, it may be unnecesary to enter into any inquiry as to the condition of the air heretofore spoken of as fresh and pure. "Fresh" and "pure" applied to air must be taken to mean the freshest and purest immediately obtainable, and that will be the same whether it be drawn in through a grated hole in a wall, or by a glazed opening close by it in the same wall. But it is a fair subject for inquiry whether,—speaking in London to Londoners,—the air about our houses in London is as pure,—or as free from impurity,— as it might be.

The out-door ventilation of large towns may be taken to be more complete above the tops of the houses and of their chimneys than it is or, perhaps, can be among and about the houses; — the processes of Nature are there not only unchecked, but are in fact aided by the heat thrown up by the chimneys into the upper air, and impurities which can be passed off by chimney flues, will be more certainly and more effectually removed and changed by Nature's chemistry, than if they are kept down to fester under foot and to exhale in our streets and about our doors and windows.

At this time every endeavour is made to provide for removing from our dwellings all excrementitious matter, and all soluble refuse, by drains into sewers, and so by the sewers to some outfall for discharge. The drain necessarily falls towards the sewer, and the sewer again to its outfall, and the sullage or soil drainage being rendered liquid thus passes in the usual course. But the usages and the necessities of civilized life cause a large proportion of the liquid refuse from dwelling-houses to pass off in a heated state, or to be followed by hot water arising from culinary processes, and from washing in all its varieties. The heat so entering the drains causes the evolution of fetid and noxious gases from the matters which go with, or have gone before, the hot water; and with these gases house-drains almost always, and sewers, commonly, stand charged. They are light fluids and do not go down with the heavy liquid matters from which they have been evolved, but they seek to rise, and constantly do rise in almost every house through imperfections or derangements of the flaps and traps which are intended to keep them down, but which only, when they do act, compel some of the foul air to enter the sewers, and there to seek outlet to the upper air which they find by the gulley gratings in the streets.

It can hardly be said perhaps that *too much* attention has been given of late to the scour of sewers by water, but it is most certain that too little attention has been given to the considerations last stated, for nothing has been done to relieve the drains and sewers of their worst offence. The evolution of foul and noxious gases in the *drains* is certainly not prevented by scouring the *sewers*. In the mean time the poison exists underfoot, and exudes at every pregnable point within and about our houses, and it rises at every grating in our streets, though the senses may become dull to them by constant suffering.

Now this is an evil which can be greatly ameliorated, if it cannot indeed, be wholly cured; but it is by a process that to be effective must be general, and, therefore, it must be added, compulsory. The process is of familiar application in the ventilation of mines, and particularly of coal mines.—An up-cast shaft containing a common chimney flue carried up at the back of every house, and connected with the house-drains at their highest level would give vent to the foul air in the drains, and discharge it into the upper air.—The foul air evolved by heat expands, and expanding it rises, and rising it would be followed by cold air settling down by the gulley gratings in the streets, thus constituting their inlets downcast shafts, and the sewers and drains themselves channels for the currents setting to the up-cast shafts, by which they would be relieved. The down draught into the sewers would carry with it much soot and fine dust, which would settle upon the liquid current and pass off with it, and so remove some of the tangible as well as the intangible impurities, before referred to, from the air in our streets and about our houses.

Much in this way might be effected by the aid of causes in con-

stant operation, but if the up-cast shaft to every house were also a fire-flue, or were only aided by the draught of a neighbouring fire, the up-current would be sufficient not only to prevent the house drains from retaining foul air, but the foul air would be thrown off into the upper air with better effect and be dissipated innocuously and without offence instead of steaming as it now does from the sewers into the air where it cannot be avoided.

W. H.

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*Arttficial Production of the Ruby, &c.*

M. EBELMAN of the Sèvre works near Paris being present with various specimens of the minerals which he has produced artificially; Mr. FARADAY stated the process and results generally to the Members. The process consists in employing a solvent, which shall first dissolve the mineral or its constituents; and shall further, either upon its removal or a diminution of its dissolving powers, permit the mineral to aggregate in a crystalline condition. Such solvents are boracic acid, borax, phosphate of soda, phosphoric acid &c.:—the one chiefly employed by M. Ebelman is boracic acid. By putting together certain proportions of alumina and magnesia, with a little oxide of chrome or other colouring matter, and fused boracic acid into a fit vessel, and enclosing that in another, so that the whole could be exposed to the high heat of a porcelain or other furnace, the materials became dissolved in the boracic acid; and then as the heat was continued the boracic acid evaporated, and the fixed materials were found combined and crystallized, and presenting true specimens of spinel. In this way crystals having the same form, hardness, colour, specific gravity, composition, and effect on light as the true ruby, the cymophane, and other mineral bodies, were prepared, and were in fact identical with them. Chromates were made, the emerald and corundum crystallized, the peridot formed, and many combinations as yet unknown to mineralogists produced. Some of the crystals of spinel of recent production which M. Ebelman exhibited had facets the eighth of an inch or more on the sides. [see *Annales de Chimie*, 1848, *tome xxii. p.* 211.] M. F.

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In the Library were exhibited:—

Cunningham's Patent Mode of Reefing Topsails [by H. Cunningham, Esq.].

Gage's Cataplasmes Galvaniques [by Dr. Bence Jones].

Specimens of Porphyritic Granite, from Fowey, Cornwall, worked by Mr. J. H. Meredith [by Mr. J. H. Meredith].

Stag-Candelabrum [by Messrs. Hunt and Roskell], &c. &c.

Cyl. ?

( COPY. )

40TH CONGRESS, 2d Session. | HOUSE OF REPRESENTATIVES. | REPORT No. 65.

# VENTILATION OF THE HALL OF THE HOUSE OF REPRESENTATIVES.

JUNE 20, 1868.—Ordered to be printed and recommitted to the Committee on Public Buildings and Grounds; and the maps accompanying the same to be referred to the Committee on Printing.

Mr. COVODE, from the Committee on Public Buildings and Grounds, made the following

## REPORT.

*The Committee on Public Buildings and Grounds, to whom was referred the resolution—*

Whereas the confined and poisonous air of the hall and corridors of the representative wing of the Capitol has caused much sickness and even several deaths among the members of this house, and under present arrangements must continue to remain in a poisonous condition:

*Resolved*, That the Committee on Public Buildings and Grounds be directed to examine at once and report to this house by what means a sufficient supply of pure air may be obtained for said hall, and that said committee be empowered to use the present means of ventilation to the best advantage for the present; and that they report by bill or otherwise—

*make the following report:*

That they have given much attention to the subject. That after examining the several reports that have heretofore been made regarding the ventilation of the hall, find the views of the most eminent men widely differing. First, as to any necessity for further ventilation; and second, should there be any need of improvement in this respect, how it could best be secured. It seemed to your committee that much of this wide difference of opinion was due to the entire want of positive facts, such as: First. How much fresh air does really enter the hall? Second. How much of the air flowing into the hall comes from the corridors, galleries, smoking-rooms, &c.? Third. Is there a fair and even distribution of the fresh air (if there is any) over the entire floor of the House, or does it all flow through one portion and leave the other portion stagnant and foul?

With the hope of eliciting some more definite information in regard to these points, your committee determined to call in the assistance of some professional men who had devoted much time to this subject. They first called upon General Herman Haupt, an engineer distinguished not less for his scientific attainments than for sound judgment and long experience.

General Haupt graduated at West Point in 1835; he has been favorably known to the chairman of the committee for more than 20 years, as chief engineer, and general superintendent of the Pennsylvania railroad. For several years he was professor of mathematics, civil engineering, and architecture in Pennsylvania College.

The systems of ventilation as applicable to mines and tunnels, also received at his hands a thorough experimental investigation, and results of the highest practical importance were elicited.

For these reasons the committee have considered the opinions of General Haupt as eminently worthy of confidence, even in opposition to the distinguished names that have been appended to previous reports.

The report of General Haupt is appended to this report.

The committee also called on Mr. Lewis W. Leeds, a gentleman who has devoted his attention exclusively to the subject of ventilation for many years past; was consulting engineer of ventilation for the Quartermaster General and Surgeon General during the war, in which service he gave the plans and directions for the ventilation of most of the government hospitals, the practical results of which have been spoken of in the highest terms by all the medical men and other officers acquainted with the operations thereof.

The system of ventilation adopted for these hospitals also received the highest commendation from the committee on sanitary arrangements at the late Paris Exposition.

Mr. Leeds is at present consulting engineer of the Treasury Department, and has arranged the ventilation for the various new buildings under the charge of that department. His report, with a number of diagrams giving a record of a large number of experiments, and giving also a summary of the results as indicated by those experiments, is also appended to this report.

Mr. Leeds's report gives the record of 26 experiments, tried on the 5th instant, for the purpose of determining the direction of the perpendicular currents in the loft over the hall of representatives. These show that the air from the loft is falling down into the hall all around the northeast and south sides of the room; it rises in the west.

Twelve different experiments show the temperature on the afternoon of the 5th to range from 44° to 48° around the exterior and only 56° on the glass ceiling, immediately over the centre of the room. At 9 o'clock on the morning of the 7th the thermometer was 38° in the loft.

Fifteen experiments tried on the morning of the 6th show these cold currents from the loft to sweep down on the outside of the galleries, carrying with them all the air contaminated by the crowds in these galleries, and pouring it over into the floor of the House; this occurs on the northeast and south sides of the House, rising on the west.

There was a strong current found to be setting *in* to the House from every external door both on the floor and in the galleries. Thus it will be seen that instead of the hall of representatives being overflowed with fresh external air, and as we have been so often told, with 40,000 or 60,000 cubic feet per minute, the truth is the floor of the House where the members sit receives the washings from the foul corridors, galleries, loft, &c., and is really the foulest place in the whole building.

There is a very small amount of air indeed coming in through the registers on the floor of the House, but this, by some, may be considered an advantage rather than otherwise, as many of them are so choked up with tobacco spittle and sweepings of the floor as to render the air rising from them very disagreeable.

Your committee have tried a number of these experiments with Mr. Leeds and find them substantially correct.

It is very evident from these experiments that the original intention of the designers must have been so mutilated by subsequent alteration as to entirely defeat the object desired to be gained, and that there is now a necessity for some decided change.

General Haupt enters into an elaborate argument to show that the carbonic acid and other impurities from the lungs and skin fall to the floor, and consequently provision should be made for the removal of the foul air from that point. He proposes leaving the entrance for the heated air at the floors as at present arranged.

Mr. Leeds quite agrees with General Haupt that the carbonic acid from the lungs falls to the floor in a still room with a temperature of 70°, and that an excess would be found there, especially where all the air enters warmer than the required temperature of the room. He thinks there should be openings for the escape of the foul air from numerous points over the floor.

Mr. Leeds says, however, that the whole system of heating *exclusively* by circulating warmed air is wrong, and that no building can ever be made comfortable and satisfactory in that way ; that where all the air is heated hotter than is required for breathing, it produces languor and debility similar to what is felt of a hot, close summer day. He says that it is absolutely necessary that there should be a considerable amount of direct radiation, and proposes that there should be several good old-fashioned wood fires, and perhaps some steam radiators placed in some portions of the room ; or, what would answer equally well, to have the sides of the walls heated to about the temperature of our bodies, or a little warmer, so as to be radiating heat to us instead of robbing us of it.

Mr. Clark, the present architect, quite agrees in this opinion, but thinks it would be better to have the fires in the cloak-rooms. He also says he thinks the present floor should be taken up, and either the whole space under the floor be used as a general hot-air chamber, or that there should be a different adjustment of the flues, as since the completion of the building one-half of the registers has been removed by parties not connected with or familiar with the original construction of the building ; and he thinks the original construction of the flues has been materially interfered with, as it is now difficult to heat the side farthest from the entrance of the warmer air to the same height by several degrees as that nearest the entrance thereof.

It must be very evident to every one, from the results given of the experiments tried, that when the gas is lighted much of the foul air and products of combustion must descend into the hall. This ought to be prevented.

Your committee believe, as expressed by Mr. Leeds, that it is essential that the direct rays of the sun should shine into every occupied room to preserve it in a pure and wholesome condition. And they believe it quite possible that some plan might be devised by which this desirable object could be accomplished at small expense and without materially changing the present construction of the building.

Your committee would recommend that a competent person should be employed to make such further examinations and experiments as may be necessary to determine the conditions of the ventilation under the various changes of wind and temperature, and that he make a report, with such plans as may be necessary for illustrating these suggestions as to the best means of improving the ventilation and the heating and lighting.

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To the Hon. JOHN COVODE,
*Chairman of Committee on Ventilation:*

An examination of the ventilation and heating of the Hall of Representatives at the Capitol has fully convinced me that very serious defects do actually exist in the present systems.

But I find, after a careful examination of the elaborate reports of Professor Henry, Dr. Wetherill, Thos. U. Walters, and others, that I am obliged to differ with these gentlemen as to the best means of ventilating this building.

In thus differing in opinion with such distinguished gentlemen, I shall feel it my duty to express fully the grounds upon which I base that opinion.

### FUNDAMENTAL PRINCIPLES OF VENTILATION.

The plans proposed for the ventilation of the hall are based on two simple propositions :

1. Heated air is relatively lighter than colder air, and will continue to ascend and the cold air to descend so long as they are free to move.

2. More or less than a given quantity of air, practically considered, cannot

occupy an apartment, and air cannot be introduced unless an equal quantity be withdrawn, or withdrawn unless an equal quantity be introduced.

These two simple and self-evident propositions will explain nearly all the phenomena observable in ventilation.

### PHENOMENA OF VENTILATION.

If heated air is introduced into an apartment containing air at a lower temperature through registers at the floors, it rises rapidly to the ceiling; and if there are openings at the ceiling it escapes without, except in a very slight degree, mixing with the air in the apartment. The air that passes off in this manner is absolutely lost and the heat imparted to it wasted. It does not remove the vitiated air contained in the lower part of the apartment; it does not form with it a homogeneous mixture, and does not communicate to it more than a small portion of its heat. But if, instead of the escape openings at the ceiling, they are placed at the floor, the phenomena observed will be widely different. The heated air will, as before, rise to the ceiling, but instead of escaping will press the colder air downwards towards the exit ducts and fill the apartment with pure warm air; the air vitiated by breathing will at once sink below the level of the mouth and in a few seconds will be carried off, no accumulation of foul air being possible. In these few words the whole theory of ventilation is in a general way presented; it only remains to make an application to the case under consideration.

### QUANTITY OF AIR REQUIRED.

In the able report of Dr. Wetherill (Ex. Doc. No. 100, 39th Congress), various opinions are given as to the amount of fresh air necessary to render the products of transpiration and respiration innocuous. These estimates, made by distinguished observers, vary from 2 to 50 cubic feet per man per minute.

These estimates are generally made upon the hypothesis that the fresh air introduced into an apartment mixes uniformly and homogeneously with the vitiated air and dilutes it to an extent sufficient to render it innocuous; but if, instead of mixing with the air of the apartment, *the warm pure air* should RISE to the ceiling and escape, all conclusions based on the hypothesis of homogeneous mixture would be fallacious; and this fallacy, it appears to your committee, pervades the whole of the very able scientific reports that have been heretofore submitted.

The House of Representatives has a capacity of 465,372 cubic feet and is supplied with 60,000 cubic feet of fresh air per minute, which Dr. Wetherill assumes will change the whole air every seven minutes and furnish to each of a thousand persons 60 cubic feet per minute.

If the whole air were changed every seven minutes or even once in an hour, the ventilation would be ample, whereas it is notoriously defective. It is obvious, therefore, that nearly all of the 60,000 cubic feet per minute must on the present system escape without performing its intended office in purifying the air.

If air that has once been respired could be immediately removed without being a second time taken into the lungs, it is obvious that so far as respiration is concerned no more air need be introduced into an apartment in a given time than can be breathed. This amount is easily calculated.

At a temperature of from 65° to 70° Fahrenheit the following average results are given by Dr. Wetherill for the respiration of an adult:

| | |
|---|---|
| Number of respirations per minute . . . . . . . | 20 |
| Cubic inches of air inhaled at each respiration . . . . . | 20 |
| Cubic inches per minute . . . . . . . . . . | 400 |

The carbonic acid exhaled is stated to be 15 cubic inches per minute and the surrounding air vitiated is $2\frac{1}{2}$ cubic feet per minute.

Four hundred cubic inches is less than one-fourth of a cubic foot, and this is all that can be taken into the lungs per minute. It would seem reasonable to suppose that if this small quantity could be removed at once, so that no portion of it could be breathed a second time, no greater amount of air for respiration could be required. Certainly it would seem that the removal of the $2\frac{1}{2}$ cubic feet vitiated by respiration would be an ample allowance. What judgment, then, should be pronounced upon the present system, which with 60 cubic feet per man per minute fails to remove the vitiated air?

The quantity of air introduced is twenty times as great as the quantity that could be vitiated by respiration, provided there was a homogeneous mixture. The facts which are daily observed prove that such homogeneous mixture does not exist under the present system.

If nineteen-twentieths of the heated air which enters the apartment escapes without being utilized, it follows that nearly all the fuel consumed in heating it has been wasted.

### POSITION OCCUPIED BY VITIATED AIR.

In the process of respiration 15 cubic inches of carbonic acid per man per minute are ejected from the lungs. This gas in course of time would diffuse itself throughout the apartment, but it is well known that its density is so great that it can be poured from one vessel into another, or if poured into an inclined trough it will flow downwards, extinguishing successively a row of lights. The specific gravity of this gas is 1.52, or 52 per cent. heavier than air. Its tendency would therefore be when exhaled to sink below the level of the mouth, and occupy the lower portions of an apartment near the floor; but it has been supposed that the elevated temperature at which it is projected from the lungs causes this gas to rise and escape at the roof. The fallacy of such an opinion can be readily proved.

Even if the temperature at which carbonic acid escapes from the lungs should be so elevated as to render it momentarily specifically lighter than the surrounding air, it would soon part with the excess of heat and then seek the level due to its superior density; but in fact, under the condition of things which actually exists, there is only about 20 degrees difference in temperature between the air when first expelled from the lungs and that of the apartment, as air increases in volume $\frac{1}{460}$ of its bulk for each degree of Fahrenheit. The effect of increasing the temperature 20 degrees would be to reduce the specific gravity less than 10 per cent. and the carbonic acid upon leaving the lungs would still be 40 per cent. heavier than the air of the apartment. It would seem impossible for this dense gas to rise to the ceiling and escape at that level without a violation of the laws of pneumatics, and yet the projectors of the present system of ventilation made no provision whatever for its escape at the level of the floor, at which level alone it is possible effectually to remove it. Mr. Clark, the present architect, seems to have appreciated the necessity of doing something to remove the carbonic acid at the level of the floor, and he provided an 8-inch tin pipe connecting with one of the registers, but an exit duct fifty times the area of the present openings in the register would not be sufficient, and the inlet and exit ducts should allow of the passage of nearly equal volumes.

### DEFECTS OF PRESENT SYSTEM.

The defects of the present system of ventilation are apparent from the preceding considerations. Although 60,000 cubic feet of heated air per minute are forced into the hall through registers in the floor, nearly the whole volume rises rapidly to the ceiling and escapes through openings provided for it without carrying with it the carbonic acid and other impurities, and this evil is greatly aggravated by the fact that not only the air vitiated by the members, but also that from the galleries, often crowded to excess, seeks the lowest level in the hall, to the great injury and discomfort of all whose seats are near the floor.

### REMEDY FOR EVILS.

The remedy is simple; it consists in an application of the principles contained in the two propositions which were enunciated at the commencement of this report. Close the openings at the ceiling and make others of area equal to the inlet registers at the floor and around the galleries. The exit ducts should communicate with flues in which a current may be maintained by means now in use, but it would, in my opinion, be greatly intensified by throwing the exhaust steam from the engine or boilers in intermittent jets into this flue, instead of allowing it, as at present, to escape without being utilized.

### PHENOMENA OF VENTILATION UNDER THE PROPOSED SYSTEM.

The heated air entering the hall through the registers would rise at once to the ceiling; unable to escape, it would accumulate and press downward the air previously in the apartment, until in seven minutes the whole of the air would be changed, the dense and foul air being carried off at the level towards which it naturally flows, and at which alone it can be removed. The operation is greatly facilitated by the large exit ducts connected with the flues. It will be perceived that, under this system, the tendency of the pure air is first upwards, in currents, and then slowly downwards. The exhaled gases sink at once below the level of the mouth, reach the floor, and are carried off. From a height of four feet above the floor they would descend and be removed in less than a minute, and it is probable that less than one-fourth of the fuel now consumed would maintain a proper temperature, as a much larger portion would be utilized.

The vitiated air from the galleries should be drawn off by flues inside the balustrade, and at the lowest level. No fears need be entertained that any considerable portion of foul air would be projected over the balustrade and into the body of the hall. All that did enter the hall in this way would be drawn off through exit openings on a level with the floor below the galleries, and there should also be a very large exit opening in the centre at the lowest level of the floor in front of the Speaker's desk. As the gallery is supported by an 18 inch brick wall, there is no difficulty in making these alterations, and the best manner of doing it can be readily determined by the intelligent architect of the Capitol. The committee have not entered upon the details; the principles involved seemed to them to be much more worthy of their careful consideration.

### MOISTURE.

I would suggest as the most simple and practical mode of moistening the air in winter, that a jet of steam from the exhaust-pipe of the engine be thrown among the heating coils, the amount of which could be regulated at pleasure, and would help to economize fuel. I also concur with Mr. Clark, the architect of the Capitol, in the opinion that, for summer ventilation, the air should be cooled and moistened by being drawn through the spray of fountains and carried over the surface of water basins at the bottom of the inlet ducts.

I also unite with Mr. Clark in recommending, in strong terms, the importance of having all the arrangements for heating and ventilation under the charge of the engineer or some other responsible and intelligent person, who, by means of suitable thermometers and hygrometers, should ascertain the temperature and the hygrometric condition of the air, and maintain both at such uniform standard as may be prescribed.

### EFFECTS OF COMBUSTION OF GAS.

It is asserted in Dr. Wetherill's report that each flame consumes as much oxygen and gives out as much carbonic acid as five human beings. This is an

additional and strong argument in favor of the proposed change in the mode of ventilation. As the gas jets above the ceiling are separated from the hall by intervening glass, the carbonic acid can be effectually prevented from entering the hall by closing the openings at the ceiling.

OBJECTIONS CONSIDERED.

It has been asserted that downward ventilation has been tried, and has not proved successful. No reliance can be placed upon a statement of this kind unless the circumstances and conditions under which the trial was made could be ascertained. Success or failure often depends on the manner of doing an act. So far as the report of Dr. Wetherill gives facts, the evidence is in favor of downward ventilation. In the observations of General Morin, page 65, it is stated that a ventilation of $14\frac{1}{3}$ cubic feet per man per minute, *principally downward*, left no perceptible odor in a lecture-room, while the *upward ventilation* of the halls of Congress, with 60 cubic feet per minute, is notoriously defective.

On page 69 is found a paragraph on "the direction the products of respiration take after leaving the body," in which it is attempted to prove that the direction is upward. The evidence in support of this position is that when the author of the report smoked a pipe at the Smithsonian Institute the smoke ascended. But the objection to this experiment is that tobacco smoke is not one of the ordinary products of respiration, certainly not in the halls of Congress. The experiment does not prove that the gray smoke which was seen to rise was carbonic acid; the experimenter does not state in what direction were the ventilating currents in the apartment, or how produced; and there was nothing in the experiment to prove that, with a gentle downward ventilation, the smoke would not have moved downwards, instead of upwards. In fact, it proved nothing at all in reference to the direction of the products of respiration.

In contradistinction to such crude experiments is the fact that a system of dowuward ventilation has quite recently been introduced into the Pennsylvania Hospital, at Philadelphia, with perfect success. It was also very extensively introduced into the government hospitals during our late war, and proved highly satisfactory. The open fireplace, too, is a very familiar illustration of the value and success of lower ventilation.

In conclusion, I would strongly urge the adoption of this system of ventilation, and recommend that the architect be directed to prepare plans at once, suggesting the most convenient method of executing the work, to be submitted to Congress.

Truly yours,

HERMAN HAUPT.

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To the Hon. JOHN COVODE,

*Chairman of Committee on Ventilation of the House of Representatives:*

I have read with care and much interest the report of General Herman Haupt on the ventilation of the House of Representatives.

I quite agree with him in his conclusions both as to theory and the necessity for putting in practice a system of exhaust for ventilation from the floor of the House.

Very extensive practice and close observation for many years past have fully convinced me that the human breath, which is the great source of contamination, in an occupied room tends first toward the floor in a still room of 70°, and that there is a probability in a closely occupied room that there will be quite an excess in the accumulation there.

This applies especially to rooms warmed exclusively by hot air.

The contrary opinion, that is, the assumption that the breath and impurities exhaled from the body rise to the ceiling and accumulate there, was advocated strongly in the ventilation of the English houses of Parliament. And as some two or three millions of dollars were spent, I believe, in endeavoring to heat and ventilate that building comfortably, and as the proceedings in regard thereto were spread over the world to an extent probably 100 times greater than any previous publication or action in regard to the ventilation of any public building, that theory of ventilation became strongly impressed upon the public mind as being the correct one.

I consider that idea erroneous; hence all theories of ventilation based upon it are consequently wrong.

But we must notice this applies to rooms warmed exclusively by heated air. We must not fall into the error the little boy did who receiving a good thick overcoat on a right cold day found it exceedingly comfortable, and, being so thoroughly convinced in his own mind of its great value, insisted on wearing it warm days too.

In the majority of our rooms the excess of the air entering (which we must of course assume to be the pure air) does not enter warmer than the contained air one-half of the time, and probably not more than one-quarter of the time.

It ought *never* so to enter. This whole theory of warming rooms exclusively by hot air is entirely wrong, and the discomfort experienced in the present halls of Congress is probably as much owing to the want of some direct radiation in the rooms as to any excess of carbonic acid present.

I have given much attention to this subject within the last year, and my observations fully confirm the opinion that no building in which all the air for breathing is heated hotter than the required temperature of the room (no matter how the air is warmed, whether by steam, hot water, or otherwise) can ever be made entirely satisfactory.

When the air breathed is nearly of the same temperature of the body it loses its invigorating influence; it produces languor and debility.

We all know the exhilarating effect of a cool bracing air of a clear, bright sunshiny day. The direct radiation from the sun is very powerful. A thermometer protected from the influence of the wind and laid in the sun of a clear bright day in winter, with the air below the freezing point, will rise to near 200°. This is the condition most favorable to active exercise, bodily or mentally, and must be approached in our artificial arrangements before real comfort can be secured.

Any member can easily satisfy himself upon this point by a few days' observation of the effect produced upon his own person while in the halls of Congress, which are warmed exclusively by heated air; and comparing that with the effect produced in a room with an open fire (if he should be so unfortunate as to be in a room heated by hot air at home as well as at the Capitol I pity him), he will soon find that five hours' labor, especially mental, will be more exhausting in the former than seven hours in the latter room, all other conditions being equal.

He will also soon notice that in the room with the open fire his head will be clear and his thoughts flow freely, while in the room heated by hot air his head will be full and oppressed, his thoughts will become confused and clouded, and to perform a certain large amount of work becomes very fatiguing both to body and mind.

I consider it absolutely essential, therefore, that some modification should be made in the manner of heating the halls of Congress.

Care should be taken, however, not to rush to the other extreme and get too much direct radiation.

A room heated exclusively in that manner, with all the fresh air entering of

the temperature of the external atmosphere, causes cold unpleasant draughts which can and ought to be avoided.

The decided preference given of late years to heating exclusively by direct radiation, over heating by circulating warmed air, shows that the former with all its objections is preferable to the latter.

The combination of the two, however, produces the most satisfactory results.

The best possible manner of applying these principles would require considerable thought and a careful examination of the building.

The open fire is one of the best sources of radiant heat; it more nearly imitates that from the sun than any other in common use.

Some persons might object to having open fires in the hall of representatives, but I don't know why it should be so objectionable. Direct radiation from steam pipes would be much less trouble, and would be preferred no doubt on many accounts for producing the greater part of the radiant heat.

Another very serious objection to heating exclusively by warmed air is that precisely the same temperature is scarcely agreeable to two persons in a hundred, and even the same person wants a constantly varying temperature according to the ever-changing conditions of his system.

It is of course exceedingly difficult, and perhaps entirely impossible, to fully meet all these varying wants, but it would not be difficult to come much nearer to it than at present.

It might be possible for steam pipes to be arranged under the floor and covered by soapstone foot-stools, so that each member could regulate the heat at his own desk at pleasure; but this might not be of sufficient importance to make it advisable to have it put in practice.

Now when the manner of heating is changed it may affect the arrangements for ventilation. One thing, however, the importance in regard to the location of the inlets and outlets of the circulating air diminishes as the proportion of the heat derived from direct radiation increases.

I believe it would be at all times and under all circumstances very desirable to have a large amount of the air drawn from the floor, as nearly as possible from under or near each member's seat, and also from under the seats of all the benches in the galleries. But to know how and when and how much to draw from the ceiling would be a much more difficult question to decide.

The openings at or near the ceiling require to be closed and opened according to the varying conditions of the room, and it can only be ascertained how they can be best regulated by experience.

That there should be such openings we all know from our every-day experience of the necessity for opening doors or lowering *external* windows (where we are so favored as to have that luxury), to relieve the upper part of the room when it gets too warm.

I think the present arrangements for introducing the air very objectionable. If there was a considerable amount of heat furnished by direct radiation, so that the inflowing air could be several degrees below the required temperature of the room, it would have a delightful refreshing effect to have it fall in gentle currents from the ceiling, and this would cause the least possible disturbance of the atmosphere, which is very essential in producing the best acoustic effect.

We all know if our feet and backs are kept perfectly warm and comfortable we are all right. We can then bear a large amount of cool refreshing air in our faces and on our heads.

To successfully heat and ventilate a large complicated building it is of primary importance that you should have a thoroughly comprehensive plan that shall include, not only the whole building, but all its surroundings.

Heat applied within any building causes movements of the air with more or less force, according to the difference of temperature of the external and internal atmosphere. The external wind is a source of considerable power. These two

forces, if properly applied, are sufficient to ventilate an ordinary building nearly every day in the year; there may be a few days, however, when the external air is almost stagnant, and it is too warm to have heat in the house; it then becomes necessary to resort to some artificial power for the movement of the air. This can be done by the application of mechanical means, as at the halls of Congress at present, or by the more simple and direct application of heat to exhaust flues.

But the important matter is in the application of this power to make it conform to and co-operate with the natural forces and merely assist their action, or otherwise make it of sufficient power to entirely overcome all these natural forces.

If much care is not exercised in the adjustment of the forces, one will just counterbalance the other, and stagnation is the result. This, I think, is frequently the case in the Capitol building.

I have never made any examination to ascertain the fact, but it seems to me probable that the air entering the hall becomes foul in passing through it and rises into the space under the roof and there becomes cool, and much of it becoming mixed with the air from the burning gas tumbles back into the room much fouler, if possible, than it went out. This reminds one of pumping little jets of pure water in all over the bottom of a muddy reservoir, by which the whole mass is kept in a constant roily, muddy condition.

There seems to be an entire unanimity among all parties as to the necessity for additional moisture. This I think of much importance.

I however doubt the propriety of allowing the steam to be discharged directly into the fresh air channels. There is often an unpleasant smell from escaping steam, and more frequently from the air driven from the steam pipes as the steam enters. This could be tried, however, very easily, and it might not be found objectionable.

Although not directly connected with the subject of ventilation, yet I would take the liberty of suggesting that I think there is a deficiency of sunlight in the hall of representatives. The sun's rays are the great source of purification, the great natural disinfectant, as well as the great moving power in the growth and development of all animal and vegetable life. We find cretinism and imbecility to predominate greatly on the shady sides of mountains. In the Russian barracks it was found that sickness and mortality were much greater on the shady side than on the sunny side, even of the same large room.

The great value of an abundant sunlight was most fully demonstrated throughout our own very extended system of barracks and hospitals occupied during our late war.

I would by no means intimate that I believe the ingenuity of man can never produce these chemical life-giving influences the same as he has already produced light almost equal, for his own limited purposes, to the great source itself. And it was certainly very creditable in the original projector of the buildings to endeavor to be as independent of all external influences as possible, and to rely as much as he well could on man's own ingenuity and resources.

But as the chemist or philosopher has not yet learned to make so much as a clover-leaf or a caterpillar, would it not be well for the present to go back to the old-fashioned plan and use a little more sunlight for the purification and disinfection of the rooms under consideration, while the chemists and philosophers are perfecting their plans, especially as sunlight can still be procured quite cheap, and is one of the few comforts of life that have not been doubled or trebled in price since the completion of these rooms. I think if a little ingenuity were exercised upon it, there would be but little alteration required and not much expense incurred in introducing sufficient to produce a very perceptible influence.

As this building is entirely different from any other building in the world, and the knowledge in regard to the subject of ventilation is still so limited, it would

seem to me to be wise on the part of Congress to employ the best talent and practical experience the country affords, to make a thorough examination and such experiments as they might require for the full illustration of the subject, and have them report in full the present condition of the ventilation, heating and lighting, and such suggestions as they might have to make for the improvement thereof.

I believe such information could thus be procured as would enable Congress to act with much more confidence, and would produce results much more satisfactory than to act upon any information it now possesses.

I am, with much respect, thy friend,

LEWIS W. LEEDS,
*Consulting Engineer of Ventilation and Heating for U. S. Treasury Department, &c.*

WASHINGTON, 1*st mo.* 13, 1868.

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*Additional Report.*

To the Hon. JOHN COVODE,
*Chairman of Committee on Ventilation of House of Representatives:*

Since making the foregoing report I have made a large number of experiments to determine the temperature and direction of the currents in various parts of the building.

I commenced at half-past 12 on the 5th and tried 63 experiments in the loft over the House in various parts to determine the directions of the currents there, a memorandum of which I enclose, marked 1, 2, and 3.

I also took the temperature in 12 different places in the loft, a memorandum of which is also enclosed, marked 4.

On the morning of the 6th I commenced an examination of the position of the registers on the floor of the House at ten minutes of 10 A. M., and also took the direction of the currents at top and bottom of all the doors opening into the hall; also the direction of the currents in 27 other places in various parts of the hall; also the temperatures at seven different points around the side of the hall. Memorandums of these experiments are also enclosed, marked 5, 6.

On the morning of the 7th I went to the House at a quarter past 7 A. M., for the purpose of ascertaining the temperatures in the loft over the hall, but as the workmen had the keys, and did not get them until half-past 8, I could not test the temperatures until 9, the sun being then two hours high—clear bright day. The results are enclosed, as well as the temperatures in the galleries and around the sides of the hall, as observed at the same time.

I had no expectation of finding the supposed conditions noticed in the preceding report (which were based upon mere theory) so nearly correct and capable of being so clearly and fully proven by these experiments.

It will be noticed by the experiments on the 5th that the temperature in the loft was 44° and 48° at 3 P. M., on the 7th at 9 A. M. it was 38° on the east end and 45° on the west end.

The experiments of the 5th show that there was a strong descending current all around the exterior of the hall, excepting the west end, from the loft into the hall, and the experiments of the 6th show this current carried over the galleries and tumbled down on to the floor of the House. The other experiments show that there is a strong current rushing in from the corridors, through all the doors, without exception, both on the floor and on the galleries.

Now when we consider the corridors are the principal ventilators for the engine-room, restaurant, water-closets, &c. &c., and then add to this most of the foul air from the galleries, it will be seen that the floor of the House is the

final receptacle of all the washing of the building, and is the foulest pit of the whole.

It will also be observed that the current is from the east side towards the west side, and there rises to the attic, and much of it from there flows across to the foul air shaft; consequently about the centre of the west side is the place where the air leaves the occupied portions of the building, and probably that is, therefore, about the foulest place in the whole building.

An examination of the condition of any of the registers will convince any member as to how much relief he can expect from them. The accompanying diagram, showing how many of the registers were open and how many closed, is merely an approximation, as so many of them were so choked up with tobacco spit, sweepings of the floor, and other trash, and there was such a foul smell coming from them, that it was difficult to determine whether to consider them closed or open.

I should think it would be well to try the experiment of reversing the fan and drawing the air *from* the floor instead of *forcing it in;* but with the present arrangement for heating and supplying fresh (?) air, it would probably merely aggravate the difficulties.

The little positive knowledge thus gained by the few experiments already tried more fully convinces me of the necessity for and value of a series of experiments, extending over a month or six weeks, and taken under all conditions of wind and weather, and when the house is crowded and when but few are there.

An entirely different condition of things will probably be found to exist when the whole lighting apparatus is in full blast.

Very respectfully,

LEWIS W. LEEDS.

WASHINGTON, D. C., 2*d month* 8, 1868.

(Annales du Conservatoire, Juin 1863.)

DES

# APPAREILS DE CHAUFFAGE ET DE VENTILATION

## à employer dans les hôpitaux,

PAR M. LE GÉNÉRAL MORIN.

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La comparaison de la mortalité dans les hôpitaux de Paris et de Londres ayant donné lieu, dans l'hiver de 1861-62, à des discussions fort animées dans le sein du corps médical et à l'Académie de médecine, l'Empereur, toujours préoccupé du sort des classes pauvres, a pensé qu'il y avait lieu d'ouvrir une enquête à cet égard et de la confier à un comité supérieur, composé des représentants de la science et de l'administration.

En conséquence, un décret impérial, à la date du 29 août 1862, a créé, sous la présidence du ministre de l'intérieur, un comité consultatif chargé de l'examen de toutes les questions relatives à l'hygiène et au service médical des hôpitaux.

Ce comité a été composé de la manière suivante :

*Président :*

S. EXC. M. LE MINISTRE DE L'INTÉRIEUR.

*Vice-Présidents :*

M. LE PRÉFET DE LA SEINE.
M. LE PRÉFET DE POLICE.
M. DUMAS, sénateur, membre de l'Institut.
M. RAYER, membre de l'Institut.

*Membres :*

MM. Claude BERNARD, membre de l'Institut.
Edmond BLANC, chef de division au ministère de l'intérieur.
Alfred BLANCHE, conseiller d'État.
BOUCHARDAT, membre de l'Académie de médecine.
BOUILLAUD, membre de l'Académie de médecine.
BOULU, médecin de l'Empereur.

MM. Combes, membre de l'Institut, directeur de l'École impériale des Mines.
Devergie, membre de l'Académie de médecine.
Gilbert, architecte, membre de l'Institut.
Husson, membre de l'Institut, directeur de l'administration générale de l'assistance publique.
Jobert de Lamballe, membre de l'Institut.
Laval, architecte des Asiles impériaux de Vincennes et du Vésinet.
de Lurieu, inspecteur général des établissements de bienfaisance.
Malgaigne, membre de l'Académie de médecine.
Mêlier, inspecteur général du service sanitaire.
Michel-Lévy, directeur de l'École impériale de médecine et de pharmacie militaires.
le général Morin, membre de l'Institut, directeur du Conservatoire impérial des Arts et métiers.
Parchappe, inspecteur général des Asiles d'aliénés.
Payen, membre de l'Institut.
Regnault, directeur de la pharmacie centrale des hôpitaux.
Reynaud, inspecteur général du service de santé de la marine.
Tardieu, doyen de la Faculté de médecine.
Trousseau, membre de l'Académie de médecine.
le baron de Watteville, inspecteur général honoraire des établissements de bienfaisance, directeur de l'Institution impériale des Jeunes Aveugles.

M. Antony Roulliet, avocat à la Cour impériale, attaché au comité.

Immédiatement après son installation par le ministre de l'intérieur, le comité répartit l'étude des questions qu'il devait examiner entre plusieurs commissions. L'une d'elles, désignée sous le titre de Commission d'hygiène des hôpitaux, fut composée de :

MM.
Le général Morin, président;
Bouillaud, président de l'Académie impériale de médecine;
Combes, membre de l'Institut et du conseil de salubrité de la Seine;
Devergie, membre de l'Académie impériale de médecine;
Gilbert, architecte, membre de l'Institut;
Husson, membre de l'Institut, directeur de l'assistance publique;
Laval, architecte;

De Lurieu, inspecteur général des établissements de bienfaisance;

Malgaigne, membre de l'Académie impériale de médecine, secrétaire;

Melier, inspecteur général du service sanitaire de la marine;

Michel Lévy, membre de l'Académie impériale de médecine, directeur de l'école de médecine du Val-de-Grâce;

Parchappe, inspecteur général des asiles d'aliénés;

Payen, membre de l'Institut et du conseil de salubrité de la Seine;

Tardieu, membre de l'Académie impériale de médecine;

Baron de Vatteville, inspecteur général des établissements de bienfaisance.

Les questions principales que cette commission devait examiner d'abord étaient les suivantes :

Quels sont les meilleurs systèmes de ventilation, de chauffage, de latrines, d'éclairage, de bains, de buanderie, de service des salles, etc. ?

Quel doit être, dans un hôpital à construire, le maximum des lits? Quel doit être le maximum des lits par salle?

Faut-il ou non des hôpitaux spéciaux par nature de maladies, et quels sont les meilleurs plans d'établissements à adopter pour des populations de 30, 100, 300 et 600 malades?

La première de ces questions est la seule dont on s'occupera dans cette note. Les deux autres ont fait l'objet de rapports particuliers approuvés par le comité, et que l'on trouvera dans le Bulletin officiel du ministère de l'intérieur.

Nous avons pensé qu'il pouvait être utile aux ingénieurs et aux architectes de connaître les motifs qui ont servi à fixer, après de longues discussions, les opinions du comité consultatif d'hygiène des hôpitaux sur la préférence qu'il convient d'accorder aux divers systèmes et appareils de chauffage et de ventilation qui ont été ou peuvent être employés dans les hôpitaux. C'est ce qui nous a engagé à reproduire *in extenso* le rapport suivant, en y joignant, sous forme de notes, désignées par les lettres A. M., quelques explications et quelques développements.

Général A. Morin.

# RAPPORT
# SUR LES APPAREILS DE CHAUFFAGE
## A EMPLOYER DANS LES HOPITAUX
## AU NOM DE LA COMMISSION D'HYGIÈNE

Par le général **MORIN**, rapporteur.

La salubrité de l'air dans les salles destinées aux malades étant l'un des objets les plus importants à obtenir, et ce but ne pouvant être atteint que par une ventilation qui assure à la fois la sortie de l'air vicié et son remplacement par de l'air nouveau, la Commission, avant d'examiner les avantages et les inconvénients que présentent les divers systèmes d'appareils de chauffage à employer dans les hôpitaux, a cru devoir poser le principe suivant : *Tout chauffage qui, par son action directe, ne détermine pas un renouvellement suffisant et régulier de l'air, ou qui n'est pas coordonné avec une ventilation convenable, est insalubre et ne peut convenir aux hôpitaux.*

Dans l'examen que l'on va faire des divers appareils de chauffage, l'on ne perdra pas de vue ce principe, et l'on reconnaîtra de suite que, sous ce rapport, les cheminées ordinaires sont l'appareil le plus simple et le plus efficace, mais dans la saison du chauffage seulement.

On sait, en effet[1], qu'une cheminée d'appartement de dimensions ordinaires, au moyen d'un feu modéré, et par des températures extérieures de 12 à 15°, peut déterminer, à elle seule, l'évacuation de 1,000 à 1,200 mètres cubes d'air par heure. Si cet appareil, d'un usage agréable, assurait aussi bien le chauffage avec économie, il laisserait peu de chose à désirer pour la saison d'hiver.

Malheureusement, l'expérience prouve que l'air évacué par les cheminées ordinaires emporte et entraîne dans l'atmosphère

1. *Études sur la ventilation*, 1er volume, p. 295 et suiv.

les 5/6 ou les 6/7 au moins de la chaleur totale développée par le combustible, et que, sous le rapport du chauffage, elles ne peuvent être considérées que comme des appareils fort peu économiques, et qui, par conséquent, ne pourraient être employés dans les hôpitaux que dans des cas particuliers.

Les cheminées ont en outre en général, l'hiver, l'inconvénient grave de déterminer des appels et des rentrées d'air extérieur d'autant plus considérables qu'elles fonctionnent avec plus d'activité. Les appareils divers d'introduction et de chauffage d'une certaine quantité d'air extérieur qu'on leur a ajoutés jusqu'à ce jour consistent dans des systèmes de tuyaux plus ou moins compliqués aboutissant à des bouches dites de chaleur, et ne remédient à cet inconvénient que dans une très-faible proportion; attendu qu'en général le volume d'air fourni par ces bouches n'est qu'une très-minime fraction de celui qui est évacué et appelé par la cheminée, et que les plus efficaces de ces appareils fournissent de l'air à une température trop élevée.

Cependant l'on peut diminuer et rendre à peu près insensible le désagrément que cause l'arrivée de l'air par les portes des pièces voisines de celles où se trouve la cheminée, en ayant soin de faire chauffer, au moyen d'un calorifère général, les escaliers, les vestibules, les corridors des bâtiments, afin que l'air qu'ils fournissent aux pièces d'habitation y afflue toujours avec facilité et à une température convenable.

L'on y trouve en outre l'avantage d'obtenir un chauffage plus économique que par l'emploi de la cheminée seule, tout en conservant l'agrément de son usage.

Mais il serait possible de disposer les cheminées de façon qu'elles participassent des qualités économiques du poêle, tout en laissant jouir de la vue du feu découvert. Il suffirait d'utiliser une partie de la chaleur emportée par la fumée, en l'obligeant à circuler en arrière dans des tuyaux disposés dans une sorte de chambre à air ayant une prise extérieure et qui verserait vers le plafond un certain volume d'air échauffé à une température que l'on modérerait en manœuvrant convenablement des registres disposés à cet effet. Divers appareils de ce genre ont été proposés et appliqués avec des succès différents, selon qu'ils ont été plus ou moins bien disposés et proportionnés. Celui que la commission anglaise chargée d'étudier la question de l'assainisse-

ment des casernes a fait adopter[1] nous paraît réaliser en grande partie les avantages que nous venons d'indiquer, et il nous semble pouvoir être perfectionné dans certains détails, afin de le transformer en appareil de ventilation pour la saison d'été.

Les bons effets de ce nouveau modèle de cheminée ont été constatés par des expériences faites récemment au Conservatoire des arts et métiers et dont les résultats sont publiés dans les *Annales* de cet établissement[2].

Nous nous bornerons, dans ce rapport, à faire connaître que les cheminées de ce modèle nouveau, convenablement proportionnées, jouissent de la propriété d'introduire dans les pièces où elles sont placées, à une température modérée de 30 à 35° et près du plafond, un volume d'air à peu près égal à celui qu'elles évacuent par le tuyau de fumée, et qu'elles réduisent ainsi à presque rien le volume d'air froid appelé par les portes et par les fenêtres. La disposition du foyer étant d'ailleurs très-favorable à l'émission de la chaleur par le rayonnement, ces cheminées présentent sur les anciennes des avantages qui nous paraissent très-importants.

La première qui ait été l'objet d'expériences faites au Conservatoire évacuait, avec un feu modéré et une consommation de 10 kilogrammes de houille au plus par douze heures, environ 500 mètres cubes d'air, et en introduisait directement à peu près 400 mètres cubes à 30°. Elle aurait donc assuré la ventilation d'une salle de huit lits à raison de 60 mètres cubes d'air par heure et par lit.

Une autre cheminée d'un plus grand modèle, plus récemment essayée, évacue 800 mètres cubes d'air et en fait rentrer à peu près le même volume à 30 ou 35°; ce qui a suffi pour chauffer une salle de 270 mètres cubes de capacité, même quand elle n'était ni meublée ni habitée.

Dans ces conditions, les cheminées ainsi perfectionnées nous paraissent être un moyen de chauffage à la fois salubre et agréable pour des salles de malades contenant un nombre restreint de lits.

L'expérience des hôpitaux anglais montre en outre que l'on peut dans une même salle placer deux cheminées de ce genre,

1. *Études sur la ventilation*, 1er volume, p. 85.

2. *Annales du Conservatoire des arts et métiers*, n° 12, 1864.

sans que leur tirage soit contrarié ; ce qui d'ailleurs résulte de la propriété qu'elles ont de fournir elles-mêmes, par l'action de l'appel qu'elles exercent, un volume d'air à peu près égal à celui qu'elles évacuent.

Rien ne s'oppose d'ailleurs à ce qu'à l'aide d'orifices spéciaux d'admission de l'air nouveau l'on puisse mélanger de l'air frais à celui des salles en telle proportion qu'on voudra, et selon le régime hygiénique qu'il conviendra d'adopter pour les malades.

Mais nous rappellerons, à l'occasion de ces cheminées, ce que nous avons dit des autres, c'est qu'il convient d'en modifier la construction de façon que, pendant la saison où le chauffage devient inutile, elles puissent cependant encore assurer l'évacuation de l'air vicié et subsidiairement la rentrée de l'air frais.

Cela est facile à obtenir à l'aide de l'introduction d'un petit calorifère à coke dans l'intérieur de la cheminée, dont le foyer serait enlevé et dont le devant serait alors presque entièrement fermé pour éviter l'échauffement des salles et ne laisser de passage que pour l'évacuation de l'air vicié. La prise d'air ordinaire de la cheminée serait également fermée, et d'autres ouvertures d'une disposition semblable seraient ménagées en différents endroits de la salle à distance de l'orifice d'appel [1].

1. Il convient cependant de faire remarquer que, la combustion dans ce petit poêle devant être beaucoup moins active que celle de la cheminée à son état normal pendant la saison du chauffage, le volume d'air évacué par ce moyen en été sera de beaucoup inférieur à celui qui serait extrait en hiver, et pourrait alors être insuffisant.

Des expériences récentes faites au Conservatoire des arts et métiers ont, en effet, montré qu'un poêle de ce genre, placé dans la cheminée qui déterminait en hiver une évacuation de 800$^{mc}$ d'air environ par heure, ne produisait, par les mêmes conduits, que la sortie de 638$^{mc}$ par heure, avec une consommation réduite, il est vrai, à 3 kil. de houille, ce qui revient à 220$^{mc}$ d'air évacué par kilogramme de houille brûlée dans des conditions défavorables.

Il faudrait donc pour obtenir, l'été, dans cette salle, l'évacuation de 800$^{mc}$ d'air vicié, employer un second appareil semblable, qu'il serait d'ailleurs toujours facile d'installer au bas d'un conduit spécial d'évacuation.

Enfin, si le démontage partiel de la cheminée, pour faciliter l'introduction du poêle, présentait quelque difficulté, l'on pourrait disposer les conduits de ventilation d'été, ainsi que leurs poêles ou fourneaux, soit à droite et à gauche de la cheminée, soit en d'autres endroits convenables de la salle.

Nous ferons remarquer que l'installation de semblables poêles ou foyers auxi-

Des expériences faites au Conservatoire des arts et métiers avec un simple fourneau de laboratoire, disposé pour essai, comme on vient de le dire, ont montré que, dans une cheminée ordinaire, on pouvait faire évacuer par kilogramme de houille brûlée environ 1,400 mètres cubes d'air, alors que la température extérieure était de plus de 18°; ce qui prouve que ce moyen simple de produire l'appel est à la fois énergique et économique.

Mais quel que soit le parti que l'on puisse tirer de cheminées ainsi perfectionnées pour le chauffage et la ventilation des hôpitaux de petite et de moyenne grandeur, les nécessités administratives pouvant conduire souvent à recourir à des appareils généraux, nous devons continuer l'examen des autres modes employés.

## DES POÊLES.

Les poêles ordinaires exigent peu d'air pour y assurer la combustion et donnent par leurs bouches de chaleur, même quand elles ont des prises extérieures, de l'air à une température habituellement trop élevée. Ils ne remplissent donc pas les conditions d'un chauffage salubre, puisqu'ils n'assurent pas même, dans l'hiver, l'arrivée et l'évacuation de volumes d'air suffisants[1].

Mais il est possible de construire des poêles en maçonnerie, disposés de manière à déterminer, dans la saison du chauffage, l'introduction d'un volume d'air élevé à une température modérée débouchant vers le plafond, et se répandant ensuite dans les salles pour y gagner des orifices d'appel pour l'évacuation de l'air vicié. Les vastes salles de l'hôpital d'accouchement et des

liaires d'appel et de leurs conduits d'évacuation de l'air vicié peut être, en temps d'épidémie, pour des hôpitaux provisoires ou pour des hôpitaux militaires en campagne, un moyen aussi simple qu'efficace d'assurer, dans la saison où le chauffage n'est pas nécessaire, une abondante et régulière ventilation. A. M.

1. Si l'application du principe posé au commencement de ce rapport est vraie pour tous les genres de chauffage, en ne considérant la question de salubrité qu'au point de vue du renouvellement de l'air, elle paraît être encore plus justifiée lorsqu'on emploie des poêles ou d'autres appareils construits en fonte. La perméabilité de cette matière par les gaz de la combustion, lorsqu'elle est fortement échauffée, semblant aujourd'hui bien établie, l'on est conduit à admettre que l'altération si désagréable que produisent dans l'air les poêles en fonte en usage dans les casernes, dans les corps de garde, dans les classes des

enfants trouvés, nommé *Gebar und Findelhaus*, à Vienne, contiennent deux poêles de ce genre, et ont trois larges cheminées d'évacuation de $0^m,65$ sur $0^m,50$ environ de section.

Pendant la saison du chauffage, qui se prolonge longtemps à Vienne, la ventilation est évaluée à 100 mètres cubes d'air par heure et par lit. Le rapporteur s'est assuré qu'au mois de mars dernier (1864) la température de l'air versé dans les salles, à près de 4 mètres au-dessus du plancher, ne dépassait pas 50 à 60 degrés.

Des dispositions analogues sont employées à l'hôpital de Béthania, à Berlin, dont les salles ne contiennent que 12 à 14 lits. Une prise d'air extérieure passant sous le plancher introduit l'air neuf dans des conduits particuliers du poêle, qui le versent près du plafond. Un autre conduit ménagé dans le massif du poêle, et communiquant avec le tuyau de fumée, sert à évacuer l'air vicié.

Ces derniers poêles sont placés au milieu des salles, de sorte que l'air vicié afflue des divers lits vers les malades qui s'approchent du foyer pour se chauffer, ce qui présente un inconvénient grave. Il faut d'ailleurs remarquer que cette ventilation, déjà insuffisante l'hiver et surtout au printemps et à l'automne, serait nulle l'été. Cependant il y aurait moyen d'améliorer un semblable dispositif et d'en utiliser le principe.

En résumé, ce n'est qu'en transformant les poêles en véritables calorifères à air chaud qu'on peut les employer avec quelque succès pour obtenir simultanément le chauffage et la ventilation pendant la saison d'hiver. Quant à celle du printemps, d'été et

colléges et partout où on les chauffe à la houille, peut être attribuée au passage d'une partie des gaz de la combustion à travers leurs parois. Ces gaz mêlés à l'air non renouvelé des locaux échauffés y produisent une altération qui peut parfois devenir funeste à la santé. Des communications récentes faites à l'Académie des sciences sur la différence très-notable de salubrité observée au Lycée de Chambéry entre les salles chauffées avec des poêles en faïence et celles qui le sont avec des poêles de fonte, ont appelé l'attention sur ce point. Il n'a pas encore été fait des expériences ni des observations décisives à ce sujet, mais l'on peut cependant regarder les poêles en fonte comme les appareils de chauffage les plus insalubres et désirer qu'ils soient bannis de tous les hôpitaux et en général de tous les lieux où un séjour prolongé des individus les rendrait dangereux pour la santé. A. M.

d'automne, il faut joindre à ces appareils des dispositions spéciales pour l'assurer.

Ajoutons enfin qu'à l'exception des petits hôpitaux, n'ayant que peu de salles, le service des poêles ne présenterait aucune économie sur des appareils généraux d'un effet plus sûr, plus régulier et d'une conduite plus facile, et qu'au point de vue de la salubrité ils sont toujours inférieurs aux autres appareils.

### CALORIFÈRES A AIR CHAUD.

Ces calorifères, tels qu'ils sont ordinairement établis par les constructeurs, ont l'inconvénient grave de donner lieu à de très-grandes inégalités dans le chauffage. Tantôt, quand le feu est actif, l'air qu'ils fournissent alors en grande quantité en sort à des températures de 80 à 100 degrés, et fatigue les organes de la respiration; tantôt, au contraire, lorsque l'alimentation du feu a été négligée, le volume d'air fourni diminue dans une grande proportion, en même temps que sa température s'abaisse.

L'on reproche en général à ces calorifères d'occasionner dans l'air qu'ils traversent une altération peu définie et de permettre par les joints de leurs tuyaux ou par les fissures qui s'y forment le passage de certains produits gazeux de la combustion, tels que de l'oxyde de carbone, etc.

Ce qui est bien reconnu, c'est que le séjour dans des locaux chauffés directement par des appareils de ce genre, tels qu'ils sont disposés le plus souvent, est pénible pour beaucoup de personnes.

Mais l'on peut remédier à une partie de ces inconvénients en faisant au préalable arriver l'air chaud fourni par l'appareil dans une capacité ou chambre de mélange, dans laquelle on se réserve la facilité de faire affluer à volonté de l'air extérieur frais en proportion suffisante pour que le mélange d'air, ainsi formé, ait une température convenable quand il est introduit dans les locaux à ventiler. L'expérience a d'ailleurs démontré que cette température doit toujours être très-peu supérieure à celle que l'on veut maintenir dans ces locaux, et, par conséquent, très-modérée une fois qu'ils ont été échauffés.

L'usage de semblables chambres de mélange, employées avec succès au Théâtre-Lyrique, à celui de la Gaîté et pour les am-

phithéâtres du Conservatoire impérial des arts et métiers, assure à l'air introduit une température convenable; mais il ne saurait suffire à l'assainissement des lieux, et il est indispensable d'y ajouter des dispositions qui déterminent l'évacuation de l'air vicié pendant la saison du chauffage.

Quant à celle d'été, pendant laquelle le chauffage est nul, il ne convient dans aucun cas de faire passer l'air nouveau par l'intérieur du calorifère, et l'on ne doit compter pour son introduction que sur les orifices d'accès de la chambre de mélange et sur les orifices auxiliaires que l'on peut ouvrir.

Cette chambre qui, dans la saison du chauffage, peut être placée dans les combles, sera en général plus convenablement établie, soit dans les caves, soit dans l'intérieur des bâtiments, parce que l'été les greniers, quel que soit le mode de couverture employé, sont généralement beaucoup trop chauds[1]. Mais lorsque la chambre sera placée dans les caves, il conviendra qu'elle soit complétement isolée des parties fréquentées, et qu'elle soit munie de doubles portes fermant aussi hermétiquement que possible, afin d'éviter l'introduction de l'air venant de l'intérieur. La prise d'air sera d'ailleurs disposée conformément aux principes posés dans le rapport sur les appareils de ventilation.

Nous pouvons, dès à présent, faire remarquer que ce que l'on vient de dire des calorifères à air chaud s'applique en grande partie à ceux où l'air est échauffé par son contact avec des capacités remplies d'eau pour modérer la température qu'il peut acquérir. A l'aide des calorifères de ce genre, la température de l'air introduit dans les salles peut être limitée à 35 ou 40 degrés. Mais cette température est encore trop élevée le plus souvent

1. Des expériences récentes, dont nous ferons connaître les résultats dans un des prochains numéros, nous ont montré que, toutes les fois que l'on pourra disposer d'une prise d'eau ou d'un moteur susceptible d'en élever, il sera facile de s'opposer à l'élévation de la température intérieure des greniers, d'une part en y ménageant de larges ouvertures qui permettent à l'air d'y circuler jour et nuit, et de l'autre en arrosant pendant les heures où le soleil donne sur la couverture toute la surface du toit avec un filet d'eau de manière à la tenir constamment mouillée. Il suffit pour cela d'y verser environ 13 litres par heure et par mètre quarré de surface de toit, ce qui pour de grands édifices, et eu égard au petit nombre de jours de grandes chaleurs, ne conduit qu'à une dépense insignifiante. A. M.

pour les locaux habités, et il importe aussi de se ménager des moyens de mêler cet air avec de l'air plus frais, surtout au printemps et à l'automne, où le chauffage doit être modéré, mais sans qu'il en résulte cependant de diminution dans le volume d'air fourni, ainsi qu'on le reproche avec raison à quelques dispositifs particuliers.

Il est bon d'ajouter que l'on peut éviter en partie l'inconvénient du contact de l'air avec des surfaces métalliques fortement chauffées en surmontant la grille du foyer par une cloche à doubles parois, toujours remplie d'eau et sur laquelle s'exerce d'abord la plus grande énergie du feu, ainsi que le font quelques constructeurs.

L'emploi de semblables cloches à eau permet de plus d'établir dans les conduits inférieurs d'air chaud une circulation d'eau à l'aide de laquelle on peut étendre à une distance plus considérable l'action des calorifères à air chaud, qui, dans les dispositions ordinaires, est limitée à 15 ou 20 mètres dans le sens horizontal.

Ce système mixte a été employé avec succès dans certains cas et en particulier, il y a quelques années, au Conservatoire des arts et métiers, par M. Léon Duvoir [1].

En résumé, les calorifères à air chaud ou les calorifères à eau chaude et à circulation d'air peuvent être employés pour le chauffage des hôpitaux, pourvu qu'il y soit ajouté une chambre où l'air qu'ils fournissent soit à volonté mêlé, dans une proportion convenable, à de l'air frais pris à l'extérieur; mais ils n'assurent par eux-mêmes que le chauffage, et doivent toujours être accompagnés de dispositions et d'appareils d'appel propres à

1. M. Péclet a beaucoup critiqué l'emploi des appareils de chauffage par circulation d'eau chaude pour des locaux qui, tels que les amphithéâtres du Conservatoire, ne doivent être chauffés que pendant quelques heures. Cette critique a été reproduite par les ingénieurs qui ont revu et publié la 3e édition de son *Traité de la chaleur*. Mais s'ils avaient mieux connu les localités ils auraient vu que cette combinaison du chauffage à l'air chaud et du chauffage à l'eau chaude était parfaitement justifiée par la nécessité de chauffer, jusqu'à une distance de plus de 15 à 20 mètres, la bibliothèque du Conservatoire pendant toute la journée et le petit amphithéâtre le soir. Des dispositions analogues motivaient aussi cette combinaison pour le grand amphithéâtre lorsqu'elle a été adoptée. Elle peut donc dans beaucoup de cas être très-utilement employée. A. M.

déterminer en tous temps une évacuation stable et énergique de l'air vicié, en même temps qu'une introduction suffisante d'air nouveau.

Lorsque l'appel de l'air vicié se fera par en bas, il sera généralement facile de profiter de la chaleur abandonnée par les tuyaux de fumée de ces calorifères pour activer cet appel, et de disposer dans le voisinage un petit foyer spécial pour produire la ventilation d'été. Aussi serait-ce la disposition générale que nous indiquerions pour le chauffage et la ventilation des grands hôpitaux, où il n'y aurait de malades qu'au rez-de-chaussée et au premier étage, toutes les fois que les conditions administratives ne permettraient pas l'usage des cheminées.

La construction des calorifères à air chaud exige plus de soin qu'on n'y en apporte ordinairement. Les tuyaux de circulation de la fumée, en tôle, doivent être bannis, parce qu'ils se dégradent trop vite, et au moins autant l'été que l'hiver quand l'air y circule, et qu'ils exposent, par conséquent, à des dangers d'incendie dont on n'a que trop d'exemples. Il est nécessaire d'exiger que tous ces tuyaux soient en fonte, ils peuvent alors durer 15 à 20 ans[1].

Il faut signaler ici un danger que présentent ces calorifères à air chaud dans leurs dispositions ordinaires et qui se manifeste souvent quand toutes les bouches de chaleur, à l'exception d'une ou deux, sont fermées. Alors la température de l'air fourni par les bouches restées ouvertes s'élève à 300° et plus, il en résulte fréquemment des incendies; mais l'usage des chambres à air fait à peu près disparaître cet inconvénient.

1. Les calorifères à air chaud peuvent être construits entièrement en briques, ainsi qu'on le fait en Russie, surtout quand ils doivent être chauffés au bois. Ils deviennent alors de véritables réservoirs de chaleur et sont d'un service plus régulier et moins assujettissant, par conséquent, que les calorifères en fonte, dont ils n'ont pas les autres inconvénients. En employant des briques réfractaires pour leur construction, on peut aussi les chauffer à la houille.

Des expériences, dont nous ferons connaître les résultats dans l'un des prochains numéros, montrent qu'à l'aide de calorifères à tuyaux en fonte bien proportionnés, dans lesquels la surface totale de chauffe des tuyaux est d'environ 70 fois la surface de la grille du foyer, la quantité de chaleur emportée par l'air chaud qu'ils fournissent, à une température moyenne de 99 à 100°, est environ des 0.60 à 0.65 de la chaleur développée par le combustible brûlé. A. M.

L'expérience des constructeurs les plus prudents les a conduits à employer dans ces calorifères 8 à 10 mètres de surface de chauffe en tuyaux pour 1,000 mètres cubes de capacité des locaux à chauffer dans les conditions ordinaires de la construction; mais dans des locaux largement ventilés, la proportion devrait être au moins doublée pour éviter la nécessité d'introduire de l'air trop chaud[1].

### CHAUFFAGE A LA VAPEUR.

La rapidité de la circulation de la vapeur sous l'action de pressions motrices assez faibles, la grande quantité de chaleur qu'elle abandonne en se condensant sont les avantages principaux de ce mode de chauffage, qui n'exige pour le passage de la vapeur que des tuyaux de faibles dimensions. Mais il a aussi, dans les dispositions le plus habituellement employées, des inconvénients assez graves.

Les inégalités dans la conduite du feu en introduisent promptement de très-sensibles dans la circulation de la vapeur; des négligences, trop fréquentes pendant la nuit, occasionnent des condensations. Lorsque le feu reprend de l'activité, la vapeur, qui afflue alors rapidement dans des conduits où un vide partiel s'est formé, rencontrant des masses d'eau liquide, les chasse violemment, et ces chocs produisent parfois des explosions, souvent des ruptures et des fuites, et très-fréquemment un bruit incommode et inquiétant.

Ces inconvénients graves ont généralement fait renoncer au chauffage direct par la circulation de la vapeur, excepté dans les usines où l'on emploie celle qui s'échappe des machines motrices, après y avoir agi. Dans ce cas, elle circule habituellement à travers de larges tuyaux apparents, ayant une pente suffisante pour que l'eau de condensation ne s'y accumule pas,

1. Le grand amphithéâtre du Conservatoire, dont la capacité, y compris toutes ses dépendances, est de 2,819 mètres cubes et où la ventilation renouvelle l'air moyennement huit fois par heure, est très-facilement chauffé par deux calorifères qui ont ensemble $64^{mq},50$ de surface de tuyaux, ce qui revient à $22^{mq},50$ par 1,000 mètres cubes de capacité chauffée. Mais l'un des calorifères étant moins bien proportionné que l'autre, je pense qu'en pareil cas 20 mètres quarrés de surface de chauffe pour 1,000 mètres de capacité serait une proportion suffisante. A. M.

et laissant à l'extrémité du circuit par la sortie de la vapeur non condensée un orifice qui permet aussi la rentrée de l'air, dans le cas où la cessation du feu amènerait un vide partiel. Mais lorsqu'il s'agit de chauffer des lieux habités, de conduire la vapeur à travers des planchers de peu d'épaisseur, les difficultés augmentent et tous les inconvénients apparaissent.

M. Grouvelle, habile ingénieur civil, a proposé et exécuté pour plusieurs hôpitaux un dispositif dans lequel la vapeur, au lieu d'échauffer directement les poêles placés dans les salles, transmet, à travers les parois des tuyaux dans lesquels elle circule, une partie de sa chaleur à de l'eau contenue dans ces poêles. Ce système, par suite de la grande densité de l'eau et de son peu de conductibilité de la chaleur, évite l'inconvénient du refroidissement trop rapide des poêles, quand la circulation de vapeur se ralentit ou cesse.

Les poêles ont, vers leur sommet, une petite ouverture qui empêche la température de l'eau de dépasser 100 degrés, et les tuyaux qui les traversent pour fournir un passage à l'air affluant de l'extérieur ne permettent pas à la température de cet air d'excéder 40 à 45°.

Des dispositions particulières donnent d'ailleurs la facilité de faire passer la vapeur par les poêles ou par des conduits extérieurs, de manière à modérer la température des salles, en ne chauffant qu'une partie de leurs poêles.

Mais, si l'on obtient par ce dispositif plus de régularité dans le chauffage, l'on n'évite pas les défauts des condensations dans les conduits qui traversent les planchers, ni les fuites toujours difficiles à trouver et à prévoir.

Quelques accidents survenus à l'hôpital Lariboisière ont même montré que ce système n'était pas tout à fait à l'abri des ruptures brusques.

Nous croyons qu'on pourrait conserver les avantages du chauffage à la vapeur et en éviter les principaux inconvénients, en disposant les tuyaux de circulation de la vapeur verticalement dans des gaînes ménagées dans l'épaisseur des murs, ou construites exprès, comme on l'a pratiqué en quelques endroits du pavillon de l'hôpital de Vincennes, ou comme l'a fait M. d'Hamelincourt pour la circulation de l'eau au bâtiment d'administration du chemin de fer du Nord.

On peut même disposer quelques-uns de ces tuyaux en forme de colonnes apparentes servant de poêles pour se chauffer les mains et les pieds, ainsi que cela se pratique dans plusieurs établissements publics d'Allemagne et de Suisse.

Ces dispositions, qui s'accorderaient très-bien avec la condition de faire arriver l'air nouveau vers le plafond[1], assureraient le retour immédiat de l'eau de condensation dans la chaudière, et atténueraient beaucoup les conséquences des fuites, auxquelles il serait plus facile de remédier que dans celle qui a été généralement adoptée jusqu'ici.

Rien ne s'opposerait toutefois à ce que l'on établît dans chaque salle un poêle à eau chauffé à la vapeur, d'après le système de M. Grouvelle, pour l'agrément des malades.

Il convient d'ajouter que, dans les hôpitaux qui doivent être ventilés, avec une surface de chauffe des poêles et des conduits de vapeur de 20 à 24 mètres carrés pour 1,000 mètres cubes de capacité des salles, on peut assurer le service du chauffage des salles à 16 ou 18° pendant les temps les plus froids. A l'hôpital Lariboisière, la proportion est de 26 mètres carrés, et elle est notablement plus grande qu'il ne serait nécessaire.

Mais il restera toujours à faire au chauffage à la vapeur, même ainsi modifié, le reproche d'être trop sensible aux inégalités du feu, et surtout aux négligences des chauffeurs, parfois prolongées pendant la nuit.

### CHAUFFAGE PAR CIRCULATION D'EAU CHAUDE.

Ce système de chauffage, qui est connu et appliqué depuis longtemps avec des dispositions diverses, est beaucoup moins sujet à permettre des variations rapides de température que le précédent, attendu qu'à capacité égale les récipients et les conduits de circulation de l'eau chaude contiennent toujours un

1. Cet air chaud pourrait au besoin être immédiatement mêlé avec de l'air froid affluant au-dessus. M. d'Hamelincourt, dans le projet qui est décrit dans ce numéro des *Annales*, présente une application heureuse qu'il a faite de cette règle. A. M.

nombre beaucoup plus considérable d'unités de chaleur que s'ils étaient remplis avec de la vapeur[1].

La grande densité de l'eau, et la permanence de sa circulation à travers les parties échauffées des appareils, longtemps après que le feu a perdu de son activité, entretiennent une assez grande régularité dans le chauffage, malgré des négligences accidentelles.

La température de l'air échauffé par ces appareils est toujours très-modérée; il est même difficile de l'élever au delà de 40 à 45° avec des surfaces de chauffe considérables. Sous ce rapport, ce genre de chauffage est très-salubre, pourvu qu'il soit accompagné d'une ventilation abondante.

Il n'est pas indispensable d'établir, comme le faisait M. L. Duvoir, dans les parties supérieures des édifices, des récipients régulateurs vers lesquels l'eau chaude s'élève, et qui, par la différence de densité de hautes colonnes d'ascension et de retour, assurent à la circulation la rapidité convenable.

Les exemples des appareils employés à l'hôpital de Guy, à Londres, au palais de Sydenham[2] et de tous les appareils de chauffage des serres, prouvent qu'il suffit d'une faible distance verticale entre les tuyaux d'ascension et de retour pour que la moindre différence de température détermine la circulation, si les tuyaux ont des sections convenables.

On en a un autre exemple très-concluant dans les appareils de chauffage de certaines baignoires.

L'on peut disposer les tuyaux de circulation de l'eau destinée à échauffer l'air, soit dans les parties inférieures des édifices, soit verticalement dans des gaînes ménagées dans les murs ou

1. Un mètre cube d'eau à 100° contient 100 cal. $\times$ 1,000 kil. $=$ 100,000 calories.

Un mètre cube de vapeur à 100° ne pèse que 0 kil., 59 et ne contient que 0,59 $\times$ 650 cal. $=$ 383,5 calories.

On conçoit donc que l'approvisionnement de chaleur existant à un instant quelconque dans un ensemble de conduits et de poêles est, à volume égal, beaucoup plus grand dans les chauffages à l'eau chaude que dans les chauffages à vapeur.

A. M.

2. Il existe dans ce palais, sous les planchers, un développement de tuyaux de circulation d'eau chaude d'environ 84 kilomètres, alimentés par vingt-cinq calorifères seulement.

A. M.

en saillie à l'intérieur et par lesquelles afflue l'air nouveau qui s'échauffe au contact des tuyaux.

La première disposition, dans laquelle les conduits sont ou peuvent être apparents sur toute leur étendue et sont disposés dans des locaux faciles à visiter, rend les fuites à peu près sans importance, permet de les reconnaître et de les faire cesser.

La seconde, qui est pratiquée par M. D'Hamelincourt, et dans laquelle on dispose ordinairement des regards à hauteur de chaque joint, laisse à peu près la même facilité et permet de rejeter au dehors les eaux des fuites.

Toutes deux sont d'une installation plus économique que celle qui a été adoptée par M. L. Duvoir-Leblanc, qui faisait circuler l'eau dans l'épaisseur des planchers, et elles sont à l'abri des reproches, un peu exagérés du reste, qui ont été adressés aux travaux de ce constructeur.

Dans ces dispositifs, les poêles à eau peuvent être supprimés totalement ou réduits à un ou deux par salle, sous forme de colonnes verticales pour la commodité des malades.

Les appareils de chauffage par circulation d'eau chaude ne donnent pas, à surface égale, autant de chaleur que ceux à vapeur. L'observation des résultats obtenus à l'hôpital Lariboisière montre qu'une surface de chauffe de 27 m. q. par 1,000 m. cb. de capacité des salles est à peine suffisante par les grands froids, et nous pensons qu'il conviendrait d'allouer au moins 30 à 32 m. q. de surface totale de chauffe pour cette capacité de 1,000 m. cb. dans des locaux analogues aux hôpitaux.

Il convient d'ajouter que les appareils de chauffage, à la vapeur ou à l'eau chaude, se prêtent également aux dispositions à prendre pour assurer à l'évacuation de l'air vicié l'activité nécessaire.

Mais la régularité, la stabilité des températures étant beaucoup mieux assurées par le chauffage par circulation d'eau chaude que l'on peut activer, ralentir ou même arrêter partiellement ou en totalité, aussi bien que dans les systèmes où l'on emploie la vapeur, nous croyons qu'il mérite, en général, la préférence, surtout pour le service des hôpitaux.

## CHAUFFAGE PAR CIRCULATION D'EAU CHAUDE A HAUTE TEMPÉRATURE.

Quant au système de chauffage par circulation d'eau chaude à haute température, connu sous le nom de système Perkins, où l'eau acquiert parfois une température supérieure à 300°, il ne peut être sans danger de faire circuler de semblables conduits dans les épaisseurs des planchers, dans le voisinage de pièces de bois qu'une si haute chaleur altère lentement et dispose à s'enflammer spontanément. Plus d'un exemple d'incendie a justifié cette appréhension.

Enfin, aujourd'hui, dans les établissements où l'on a adopté ce système de chauffage, tous les tuyaux en fer étiré sont apparents et suspendus aux murs ou aux plafonds, ce qui est d'un aspect fort disgracieux. Il est d'ailleurs indispensable d'entourer d'un grillage ou d'une enveloppe à distance les portions de ces tuyaux qui sont à portée du contact, pour éviter des accidents graves.

Par tous ces motifs, nous ne croyons pas qu'il convienne, dans aucun cas, d'employer, pour le chauffage des hôpitaux, le système Perkins ou de circulation d'eau à haute température.

En terminant, il n'est pas inutile d'ajouter que, d'après les résultats généraux connus jusqu'à ce jour, le chauffage par circulation d'eau chaude avec ventilation a été trouvé plus économique que le chauffage par les calorifères ou par les poêles, même sans ventilation, de sorte qu'il leur est préférable, sous tous les rapports.

Quant à la dépense d'installation des appareils destinés à assurer à la fois le chauffage et la ventilation des hôpitaux, elle s'est élevée pour les appareils de :

Chauffage par la vapeur et de ventilation par insufflation de MM. Thomas et Laurens à. . . . . . . . . . . . . 808 fr. par lit.

Chauffage par circulation d'eau chaude et de ventilation par aspiration de M. L. Duvoir-Leblanc à. . . . . . . . . . . . . . . . . . . . . . . . 480 fr. par lit.

Il est certain que des appareils basés sur les mêmes principes que ce dernier, mais d'une disposition plus simple et aussi efficace, pourraient être aujourd'hui établis à beaucoup moins de

frais. Nous pouvons en fournir pour preuve un projet de chauffage par l'eau chaude avec ventilation par appel, préparé par les soins du rapporteur pour un très-petit hôpital de 16 lits répartis dans deux salles. La dépense d'établissement supposée faite en même temps que la construction ne s'élève, d'après le devis accompagné d'une soumission, qu'à 200 francs par lit, et elle serait évidemment moindre à proportion pour un hôpital plus considérable.

Le chauffage et la ventilation par les cheminées modifiées, comme nous l'avons indiqué, seraient encore d'une installation beaucoup moins dispendieuse, et, pour le même projet d'hôpital de 16 lits, la dépense ne s'élèverait au plus qu'à 100 francs par lit.

Il est d'ailleurs évident que, dans beaucoup d'hôpitaux existants, dont les salles ne seraient pas très-grandes, l'on pourrait, sans difficultés, substituer ce dernier système à l'usage insalubre des poêles.

En résumé, les appareils de chauffage qu'il convient d'adopter pour l'ensemble des bâtiments des grands hôpitaux doivent être classés dans l'ordre de préférence suivant, sous la réserve de l'influence que des considérations locales peuvent exercer sur le choix à faire :

1° Appareils de chauffage par circulation d'eau chaude;

2° Appareils de chauffage à la vapeur avec poêles ou récipients d'eau ;

3° Calorifères à air chaud, avec ou sans cloche à eau, et avec chambre de mélange de l'air frais.

Mais pour les hôpitaux qui n'ont que de petites salles, il y aura lieu de préférer à ces appareils, pour le chauffage et pour la ventilation des salles, l'usage des cheminées disposées comme nous l'avons indiqué plus haut et qui sont faciles à installer dans des hôpitaux existants.

Dans ce cas, il pourrait encore être avantageux d'établir des poêles, ou un calorifère général, pour chauffer les cages d'escaliers, les corridors et les abords des salles.

En établissant, comme elle vient de le faire, un ordre de préférence entre les différents appareils à employer, la Commission n'entend pas prescrire des règles absolues, parce qu'elle ne méconnaît pas qu'il faut, dans tous les cas, tenir compte des con-

ditions administratives et locales qui peuvent exercer une grande influence sur le choix à faire.

Le rapport qui précède a été lu et discuté en séance du comité le 2 février 1865.

Le comité, après en avoir voté successivement les conclusions, l'a adopté dans son ensemble.

*Le vice-président,*
RAYER.

*Le secrétaire,*
DEVERGIE.

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# APPAREILS DE VENTILATION

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En reproduisant ici *in extenso* le rapport du comité d'hygiène du service médical des hôpitaux relatif aux appareils de ventilation qu'il convient d'employer dans les hôpitaux, nous devons faire remarquer qu'il ne s'agit dans ce rapport que de la comparaison des divers dispositifs proposés ou essayés au point de vue des effets physiques ou mécaniques qu'ils peuvent réaliser. Il n'est et il ne pouvait, dans cette partie des travaux du comité, être nullement question des effets physiologiques et de l'influence de ces dispositifs sur la santé des malades.

Quoique quelques hôpitaux soient dotés d'appareils de ventilation plus ou moins parfaits depuis près de vingt ans, les données régulières d'observation manquent à peu près complétement pour la solution de cette dernière et si importante question.

Tout ce que les recherches de divers observateurs et nos propres expériences, ainsi que la discussion des résultats obtenus, nous ont appris, se réduit à nous permettre d'établir que tel ou tel dispositif est susceptible, quand il fonctionne à son état

normal, de déterminer l'évacuation et l'introduction de certains volumes d'air, qu'il présente certains inconvénients, qu'il devrait recevoir certaines modifications, etc., etc., et enfin nous autoriser à nous prononcer sur les principes qui doivent guider dans le choix des dispositifs proposés.

Mais en ce qui concerne les effets réels, journaliers, réguliers produits pendant toute l'année par ces mêmes appareils depuis qu'ils existent, sous le simple rapport du renouvellement de l'air, l'administration est restée jusqu'à ces derniers temps dépourvue de tout moyen régulier de contrôle indépendant de l'exactitude et de l'intelligence de ses agents. L'on ne saurait lui en faire reproche, puisque ces moyens n'existaient pas, ou plutôt que ceux que l'on connaissait exigeaient le concours d'expérimentateurs un peu exercés.

Mais la conséquence de cette absence de moyens de contrôle n'en est pas moins très-fâcheuse, en ce qu'elle ne permet pas encore aux médecins d'établir entre les hôpitaux pourvus d'appareils de ventilation et ceux qui n'en ont pas des comparaisons basées sur une marche régulière et normale de ces appareils, et qu'il en résulte pour quelques médecins des doutes sur l'efficacité réelle d'un abondant renouvellement de l'air dans les hôpitaux.

Aujourd'hui, les instruments qui ont manqué jusqu'ici existent, quelques-uns fonctionnent avec continuité, et ils permettront bientôt à un directeur d'hôpital de s'assurer, sans sortir de son cabinet, si le service de la ventilation se fait avec la régularité prescrite. Dès lors, cette régularité pourra être obtenue et l'appréciation des résultats physiologiques et hygiéniques deviendra possible avec plus de précision que par le passé.

Quoi qu'il en soit, il est assez évident *a priori*, et nos organes nous rendent assez sensibles les avantages d'une ventilation abondante et régulière, pour qu'il n'y ait aucun doute sur l'utilité et la nécessité d'un renouvellement constant et continu de l'air dans les salles des hôpitaux, et la question du choix des dispositifs à adopter conserve toute son importance. A. M.

# RAPPORT
# SUR LES APPAREILS DE VENTILATION
## AU NOM DE LA COMMISSION D'HYGIÈNE DES HOPITAUX

Par le général **MORIN**, rapporteur.

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Après s'être occupée des conditions d'établissement des hôpitaux généraux et spéciaux, du nombre et de la grandeur des salles, de leur disposition intérieure au point de vue du bien-être des malades, et des facilités du service, la Commission a porté ses études sur les questions qui se rattachent à l'hygiène et à la salubrité. Elle a indiqué le choix à faire pour la situation, pour l'exposition des bâtiments, les proportions à adopter pour la surface horizontale et pour l'espace cubique à allouer à chaque lit de malade, et elle s'est ensuite appliquée à l'étude des questions, fort controversées dans ces dernières années, qui se rattachent à la ventilation et au chauffage de ces asiles.

Depuis longtemps déjà, la sollicitude des administrations hospitalières s'était préoccupée de la recherche des moyens les plus sûrs à employer pour renouveler, dans les salles de malades, l'air incessamment vicié par les émanations plus ou moins insalubres produites par les individus souvent trop nombreux qui s'y trouvent réunis, et pour le remplacer par de l'air nouveau aussi pur que possible.

Dès l'année 1846, mettant à l'essai des dispositions appliquées depuis 1825 au palais du Conseil d'État et en d'autres lieux par feu Léon Duvoir-Leblanc, elle introduisait dans l'un des pavillons de l'hôpital Beaujon le système de chauffage par circulation d'eau chaude et de ventilation par aspiration de cet ingénieux constructeur, chez qui l'intelligence suppléait à l'instruction première. Cet essai, malgré son succès bien constaté sous le rapport de l'évacuation de l'air vicié, laissait à désirer sous celui de l'introduction régulière et convenable de l'air nouveau. Trop exclusif et, comme tous les inventeurs, trop confiant dans l'effi-

cacité des moyens, fort rationnels d'ailleurs, qu'il employait, Léon Duvoir n'avait pas suffisamment assuré la rentrée de l'air nouveau en toute saison ; et cependant les médecins chargés du service dans cet hôpital avaient cru pouvoir constater que, tels qu'ils étaient, les appareils de ventilation avaient produit, dans la salubrité du pavillon qui en était pourvu, une amélioration considérable, qui influait notablement sur le rétablissement des malades.

Satisfaite de ce premier succès, l'administration des hôpitaux se décida à faire établir des appareils du même système dans l'un des pavillons de l'hôpital Necker, destiné aux femmes malades, et les résultats constatés par une Commission composée de MM. Combes, membre de l'Institut, Leblanc (Félix), répétiteur à l'École polytechnique, Gauthier, architecte, membre de l'Institut, et Huvé, architecte, montrèrent que, pendant l'été comme pendant l'hiver, le volume d'air vicié évacué par les appareils pouvait s'élever de 60 à 70 mètres cubes par heure et par lit, et même parfois dépasser de beaucoup ces chiffres.

La création du vaste hôpital qui porte aujourd'hui le nom d'*Hôpital Lariboisière* offrait à l'Administration une nouvelle et importante occasion de continuer les améliorations qu'elle avait déjà si heureusement introduites dans son service. Un projet complet pour cet hôpital avait été demandé en 1847 au même constructeur et examiné par une Commission, qui y avait indiqué diverses modifications ayant pour but d'accroître les moyens d'évacuation de l'air vicié et d'introduction de l'air nouveau[1].

Les événements de 1848 ayant fait ajourner la solution de la question, et des dispositifs différents ayant été proposés et présentés en 1852 à l'Administration comme résolvant le problème d'une manière à la fois plus sûre et plus économique, elle se décida à mettre la question au concours.

Mais, revenant sur les bases qu'elle avait précédemment admises, elle crut à ce moment devoir se borner à exiger :

1° Une ventilation continue d'air chaud pendant l'hiver, et d'air froid pendant la saison chaude, à raison d'au moins 20 mètres cubes par lit et par heure dans les salles de malades,

1. Cette commission était composée de MM. le lieutenant-colonel Morin, Gauthier de Claubry et Robinet.

2° Et une ventilation, pendant le jour seulement, dans les chauffoirs à raison de 10 mètres cubes par lit du pavillon correspondant.

C'était, il faut le dire, rétrograder et méconnaître les résultats de l'observation, qui avaient montré qu'à l'hôpital Beaujon et à l'hôpital Necker, si un renouvellement d'air obtenu à raison de 60 mètres cubes par heure et par lit avait constitué une grande amélioration, ce chiffre, bien supérieur à ce qui avait été jusqu'alors indiqué par la science, était encore à peine suffisant.

Aussi, lorsque l'un de nous, consulté par le ministre de l'intérieur au sujet des divers projets présentés au concours pour l'hôpital Lariboisière, dut donner un avis, crut-il devoir s'exprimer en ces termes[1] :

« Je crois donc, Monsieur le ministre, abstraction faite de « toute considération des différents systèmes proposés, devoir « vous prier d'exiger que le minimum du volume d'air expulsé « par lit des salles de malades soit fixé à 60 mètres cubes par « heure, et, pour les promenoirs, à 20 mètres cubes, avec obli- « gation de doubler cette quantité, dès que l'administration en « reconnaîtrait la convenance ou la nécessité, sans que la dépense « excédât dans une proportion donnée (20 pour 100 par exem- « ple) la dépense normale. »

Plus loin, le même rapporteur, au sujet des deux principaux systèmes mis en concurrence et dont l'un, celui de M. Léon Duvoir-Leblanc, procédait par aspiration, et l'autre, celui de MM. Thomas, Laurens et Farcot, opérait par insufflation, s'exprimait en ces termes :

« S'il ne s'agissait que de faire un essai comparatif sur l'un ou « l'autre des bâtiments ou même sur la moitié de part et d'autre, « je n'hésiterais pas, parce que, sans me préoccuper des inté- « rêts financiers, je ne verrais dans cette tentative, qui, dans les « deux cas, assurerait au moins de chaque côté une améliora- « tion considérable, qu'une grande expérience dont le résultat « final, en apportant au régime des hôpitaux un immense per- « fectionnement, donnerait les moyens sûrs de le généraliser.

« C'est à vous, Monsieur le ministre, qu'il appartient d'appré-

1. Rapport adressé à M. le ministre de l'intérieur par le général Morin. (Mai 1852.) *Études sur la ventilation*, page 131, 1er volume.

« cier toute l'importance de la question à ce point de vue géné-
« ral, et de ne pas la circonscrire à l'hôpital du Nord. »

Puis il terminait ainsi :

« Je conclus donc à ce que les appareils de M. Léon Duvoir-« Leblanc soient adoptés pour trois des bâtiments de l'hôpital « du Nord, et ceux de MM. Farcot, Grouvelle, Thomas et Lau-« rens pour les trois autres.

« L'avenir décidera quel est celui des deux systèmes dont « l'emploi doit être généralisé. »

Cette solution fut approuvée par le ministre, et c'est à cette circonstance qu'est dû l'établissement simultané des deux systèmes qui fonctionnent à l'hôpital Lariboisière, et qu'il faut attribuer la facilité que nous avons eue de les comparer dans des conditions à très-peu près identiques.

Plus tard, l'administration de l'Assistance publique, justement frappée des dépenses considérables qu'avaient entraînées ces installations, malheureusement faites après la construction des bâtiments (comme cela n'arrive que trop souvent), consentit à faire établir, d'abord comme essai, à l'hôpital Beaujon, et ensuite, à titre définitif, à l'hospice Necker, un autre système de ventilation par insufflation et de chauffage par l'air chaud, proposé par un médecin belge, le docteur Van Hecke, système qui a été aussi appliqué à l'Asile impérial du Vésinet.

Enfin, d'autres dispositifs ont été introduits, dans ces dernières années, à l'hôpital de Vincennes par le service du génie : ils procèdent par l'aspiration.

On voit, par cet exposé général des tentatives faites par l'administration des hospices de la ville de Paris, et plus tard par celle de l'Assistance publique qui lui a succédé, qu'elles n'ont reculé devant aucune dépense pour assurer à nos hôpitaux une ventilation susceptible d'y maintenir la salubrité. Si l'examen des résultats obtenus, si la discussion des nombreuses expériences faites par divers observateurs nous conduisent à des conclusions différentes de celles que l'Administration avait cru d'abord pouvoir accepter, il n'en est pas moins juste de reconnaître que, si nous sommes parvenus à énoncer des principes, à formuler des règles qui permettent d'obtenir à l'avenir des résultats stables et satisfaisants, nous n'aurions pu y arriver sans les lumières que nous avons puisées dans l'étude des appareils

établis par ces administrations et dans celle des expériences qu'elles ont provoquées, fait faire ou facilitées.

Chaque jour, en amenant quelque progrès nouveau dans les connaissances humaines et dans les arts, nous oblige tous à modifier nos idées et nos jugements, et de pareils changements dans les opinions, non plus que les discussions qui les amènent, ne sauraient être regardés comme une critique des travaux antérieurs, auxquels il est, au contraire, du devoir de tout appréciateur impartial de rendre pleine et entière justice.

Mais l'étude des travaux exécutés en France ne devait pas être la seule qui fût susceptible de jeter du jour sur l'importante question confiée à votre Commission, et elle avait aussi à tenir compte des tentatives plus ou moins heureuses faites à l'étranger, et plus particulièrement en Angleterre. Diverses publications, des renseignements fournis par M. le docteur Lefort, ainsi que des documents recueillis par l'un de nous, nous ont servi à compléter nos recherches sous ce rapport.

Après ce préambule nécessaire pour faire connaître la situation générale du problème et les dispositions que la Commission apportait à l'étude des questions qu'elle avait à examiner, il convient d'indiquer la marche qu'elle a suivie pour parvenir à leur solution.

Sans se préoccuper aucunement d'abord des différents dispositifs employés ou proposés, elle a cherché à bien préciser le but et les conditions d'une bonne ventilation, en se réservant de partir de ces prémisses pour l'examen ultérieur de ces dispositifs.

### VOLUME D'AIR A RENOUVELER PAR LIT DANS LES HÔPITAUX.

Avant de s'occuper des moyens à employer pour assurer le renouvellement de l'air dans les salles et dans les dépendances d'un hôpital, il était naturel de fixer les idées sur le volume d'air nécessaire à l'assainissement de ces locaux.

Les opinions ont été, jusqu'à ces derniers temps, fort partagées à ce sujet, et les données de la science physiologique n'ayant pu servir à les fixer, il faut recourir à l'expérience pour déterminer ces volumes, en tenant compte des conditions particulières aux hôpitaux.

Sans rappeler les évaluations successives des commissions d'hygiène, qui, en 1843, regardaient un volume de 10 mètres cubes d'air par heure et par malade comme suffisant, et sans revenir sur celle de 20 mètres cubes que l'Administration des hôpitaux adoptait dans le programme de 1852 pour l'hôpital Lariboisière, nous nous contenterons de dire que l'ensemble des observations a conduit presque tous ceux qui se sont occupés de la question à reconnaître aujourd'hui que, pour les salles de malades ordinaires, ce volume doit être, au minimum, de 60 mètres cubes par heure et par lit.

Une observation faite par l'un de nous à l'hôpital Lariboisière a montré en effet qu'on ne pouvait, sans inconvénients, diminuer sensiblement ce volume[1]. Dans le courant du mois de février 1861, le nombre des malades reçus dans cet hôpital s'étant beaucoup augmenté, on a été dans la nécessité d'installer, dans quelques-unes des salles et, en particulier, dans celles du pavillon n° 4, des lits supplémentaires, de sorte qu'au premier et au second étage, le nombre des lits a été porté de 32 à 42 ou 44; dès lors la ventilation habituelle, qui n'est en moyenne que de 60 à 70 mètres cubes par heure et par lit, quand il y en a 32, s'est trouvée réduite à 45 ou à 53 mètres cubes, et est devenue tout à fait insuffisante; une odeur très-forte et très-désagréable régnait dans ces salles : au dire des malades, l'infection était surtout très-intense pendant la nuit.

L'on a alors activé l'évacuation de l'air vicié, en allumant dans la cheminée générale 53 becs de gaz, qui y avaient été placés pour des expériences spéciales, et le volume d'air évacué s'étant élevé à 7,250 mètres cubes environ, et le nombre des malades dans ce pavillon étant alors de 120, on a ramené la ventilation au chiffre de 60 mètres cubes environ d'air par heure et par lit : l'amélioration dans la salubrité de l'air a été immédiate.

On voit donc que, si l'extraction d'un volume de 60 mètres cubes d'air par heure et par lit suffit à peine pour entretenir l'air des salles à un degré acceptable de pureté, celle d'un volume de 45 mètres cubes était tout à fait insuffisante.

Le volume de 60 à 70 mètres cubes d'air par heure et par lit est aujourd'hui admis par l'administration de l'Assistance pu-

1. *Études sur la ventilation*, 1er vol., page 345.

blique comme base des dispositions à prendre pour la ventilation des hôpitaux dans les cas ordinaires.

Mais pour les salles de blessés, dans lesquelles des plaies purulentes exhalent souvent une odeur fétide, et où, par suite, se déclarent fréquemment des affections érésypélateuses ou autres, et pour les hôpitaux de femmes en couches, il nous a paru nécessaire d'élever ce volume à 80 ou 100 mètres cubes en temps ordinaire, et à 150 mètres cubes en temps d'épidémie[1].

Quant aux hôpitaux destinés aux enfants et aux hospices où sont reçus les vieillards ou les aliénés, une ventilation calculée à raison de 30 à 40 mètres cubes par heure et par individu nous paraît suffisante.

En résumé, votre Commission vous propose de fixer ainsi qu'il suit les volumes d'air à renouveler dans les salles des hôpitaux :

| | Par heure et par individu. | |
|---|---|---|
| Malades ordinaires . . . . . . . . . | 60 à 70 | mètres cubes. |
| Blessés et femmes en couches. . . . | 80 à 100 | — |
| En temps d'épidémie. . . . . . . . | 150 | — |
| Enfants. . . . . . . . . . . . . . . . | 30 | — |
| Dans les hospices de vieillards. . . | 40 | — |

La condition d'augmenter le volume d'air normal dans une proportion considérable exige nécessairement que des dispositions spéciales soient prises pour assurer cet accroissement.

## CONDITIONS ET BUT DE LA VENTILATION.

Ces bases étant posées, votre Commission, avant d'entrer dans la discussion des systèmes de ventilation proposés ou employés jusqu'à ce jour, a dû chercher à bien préciser le but à atteindre et les conditions auxquelles il faut satisfaire.

Le renouvellement de l'air dans les lieux habités n'étant rendu nécessaire que par l'altération qu'y produisent les émanations

1. Le volume de 100 mètres cubes d'air par heure et par lit est aujourd'hui admis comme base de la ventilation des hôpitaux de femmes en couches de Vienne et de Saint-Pétersbourg.

du corps, ou par la chaleur qu'y développent les individus ou les appareils d'éclairage, et souvent par ces deux causes réunies, il a paru évident à votre Commission qu'elle devait admettre pour base de ses discussions le principe suivant :

*La ventilation hygiénique des hôpitaux doit avoir pour but et pour effet principal d'extraire l'air vicié des lieux et des points mêmes où il se produit.*

Mais, toute extraction d'air d'un espace quelconque qui n'est pas hermétiquement clos et dans lequel le vide ne peut exister impliquant nécessairement la rentrée de l'air nouveau, on ne doit pas, dans la solution des questions de ventilation, séparer l'étude des dispositions à prendre pour assurer la rentrée de l'air de celles qui ont pour objet son extraction.

Cependant, quoique ces deux questions soient connexes et très-étroitement liées l'une à l'autre, la première (celle de l'extraction) est évidemment la plus importante; la seconde n'en est que la conséquence forcée. Cela est si vrai que, quand la solution de la première est assurée, la nature seule se charge presque toujours d'une grande partie de celle de la seconde. Les cheminées ordinaires d'appartement et l'appel d'air qu'elles exercent de l'extérieur vers l'intérieur en fournissent un exemple trop évident pour qu'il soit nécessaire d'en citer d'autres.

Partant de ces considérations, la Commission a décidé qu'elle examinerait d'abord les divers systèmes à comparer au point de vue de l'énergie, de la régularité et de la stabilité qu'ils sont susceptibles d'assurer à l'évacuation de l'air vicié.

## SYSTÈMES DIVERS DE VENTILATION EMPLOYÉS.

Sous des formes et avec des dispositions différentes, deux systèmes de ventilation étaient à comparer : l'un, le plus ancien de beaucoup, en usage de temps immémorial dans les mines les plus profondes, représenté dans nos habitations par les cheminées, détermine l'évacuation de l'air vicié des lieux à ventiler par l'excès de la température de l'air dans un puits ou dans une cheminée d'évacuation sur la température extérieure ou, ce qui revient au même, par l'excès de la densité de l'air extérieur sur celle de l'air qui circule dans la cheminée.

La théorie[1] et l'expérience sont d'accord pour montrer que le volume de l'air évacué est proportionnel, toutes choses étant égales d'ailleurs,

1° A l'aire de la section transversale de la cheminée;

2° A la racine carrée de la hauteur de la cheminée;

3° A la racine carrée de l'excès de la température de l'air dans la cheminée sur la température extérieure.

Ce mode de ventilation porte le nom de *ventilation par aspiration*. L'excès de température qu'il est nécessaire de maintenir dans la cheminée est ordinairement obtenu dans les mines et dans certains édifices, comme à la prison Mazas, au Conservatoire des arts et métiers, etc., au moyen de foyers allumés au bas des puits ou conduits d'évacuation. Dans d'autres cas, on se sert de récipients, dans lesquels circule de la vapeur ou de l'eau chaude. Enfin, la chaleur développée par la combustion du gaz peut être utilisée, soit d'une manière permanente, soit accidentellement, selon les besoins.

Quel que soit le mode d'échauffement de l'air, et quelle que soit la température extérieure, toutes les fois que la température dans le conduit d'évacuation dépassera d'un même nombre de degrés celle de l'air extérieur, la vitesse dans ce conduit et, par conséquent, le volume d'air écoulé seront les mêmes : c'est, comme nous venons de l'indiquer, ce que nous apprend la théorie aussi bien que l'expérience; nous aurons plus loin l'occasion de le vérifier.

Tel est, dans son ensemble et dans ses conditions fondamentales, le système de la ventilation par aspiration.

Quelquefois, cependant, on remplace l'action de la chaleur par celle d'un ventilateur aspirant, que l'on établit alors le plus souvent à la partie supérieure du puits ou conduit d'extraction. Ce dispositif est employé dans les mines pour la ventilation proprement dite, et plus souvent dans les aiguiseries et dans les usines où se développent des poussières dangereuses ou incommodes.

La condition de stabilité de l'évacuation se réduit alors à peu près à celle de la constance de la vitesse du ventilateur.

Le second système, qui a reçu le nom de *ventilation par insuf-*

1. *Études sur la ventilation*, tome Ier, pages 168 et suiv.

*flation* ou *par pulsion*, est basé sur l'emploi d'appareils mécaniques, et en particulier de ventilateurs plus ou moins puissants qui, par des conduits ordinairement placés sous le sol, dans les murs et enfin sous une partie des planchers, font pénétrer dans les salles à ventiler de l'air refoulé par leur action, et déterminent nécessairement la sortie d'un volume égal par les orifices qui peuvent permettre cette évacuation.

Les partisans de ce système, pensant que cette affluence de l'air dans les salles devait y produire un accroissement de pression assez notable, en ont conclu que l'air intérieur vicié serait ainsi forcé de s'écouler par les orifices et par les conduits d'évacuation ménagés à cet effet, et que, pourvu que la vitesse de marche du ventilateur fût suffisante et constante, celle de l'introduction de l'air refoulé le devenant aussi, il en serait nécessairement de même de l'évacuation par les conduits disposés dans ce but. On verra plus loin que ni l'une ni l'autre de ces conclusions ne sont exactes; la dernière surtout beaucoup moins que la première.

Il résulte de la description générale que nous venons de donner des deux systèmes de ventilation que, dans celui de l'aspiration, les mouvements de l'air sont analogues à ceux de l'eau dans une pompe aspirante, l'air évacué étant nécessairement remplacé par de l'air nouveau, et qu'à l'inverse celui de l'insufflation devrait opérer à la manière des pompes foulantes, en obligeant à sortir des salles un volume d'air vicié égal à celui qui y serait entré.

Nous verrons plus loin à quelles conditions le premier système peut réaliser les effets proposés, et s'il est possible que le second parvienne à satisfaire à celle d'une expulsion régulière et stable de l'air vicié. Mais, dès à présent, il y a lieu de faire remarquer que, par suite des différences naturelles et inévitables de la température de l'air admis, de l'air évacué et de l'air extérieur, l'aspiration doit toujours participer, dans une certaine proportion, aux effets des appareils d'insufflation : c'est ce que l'expérience nous montrera.

## DISPOSITIONS GÉNÉRALES ADOPTÉES A L'HOPITAL LARIBOISIÈRE.

Il ne peut être question, dans ce rapport, de comparer les ré-

sultats de l'application de ces deux systèmes qu'en ce qui concerne spécialement les hôpitaux, et, pour le faire avec quelque clarté, il est nécessaire de donner une idée sommaire des dispositions générales employées pour obtenir dans les salles de malades l'évacuation de l'air vicié le plus près possible des points où l'infection se produit, c'est-à-dire près des lits des malades, sans qu'ils en soient incommodés.

Afin de faire cette comparaison de la manière la plus équitable, nous choisirons d'abord pour termes les dispositions adoptées pour les pavillons de l'hôpital Lariboisière, où sont établis d'une part, dans les trois pavillons n$^{os}$ 1, 3 et 5, destinés au service des femmes, les appareils de ventilation par aspiration et de chauffage à l'eau chaude du système de M. Léon Duvoir-Leblanc, et, d'une autre part, dans les pavillons n$^{os}$ 2, 4 et 6, les appareils de ventilation par insufflation, et de chauffage par la vapeur, du système de MM. Farcot, Thomas et Laurens.

Dans chacun de ces pavillons, à trois étages, il y a trois salles contenant chacune 32 lits et trois petites chambres à 2 lits, ce qui donne 96 lits pour les grandes salles, 6 pour les petites chambres, et en tout 102 lits par pavillon à l'état normal.

Les bâtiments sont simples, éclairés sur chacune des deux faces par huit fenêtres. Deux lits sont placés devant chaque trumeau, à 0$^{m}$,40 ou 0$^{m}$,50 du mur, et, dans l'intervalle de ces deux lits, un conduit d'évacuation vertical, partant du niveau du plancher, est destiné à l'extraction de l'air vicié. La disposition des deux groupes de pavillons est identique sous ce rapport, ainsi que sous celui des autres détails généraux de la construction.

Les conduits d'évacuation de l'air vicié particuliers à chaque étage s'élèvent dans les trumeaux jusqu'au niveau du grenier, où ils débouchent dans des conduits horizontaux qui dirigent l'air extrait vers une cheminée générale d'évacuation commune aux trois salles d'un même pavillon.

Mais, dès à présent, il importe de signaler une différence assez notable qui existe entre les deux groupes de pavillons, dans la disposition de ces derniers conduits et des cheminées.

Dans ceux (n$^{os}$ 1, 3 et 5), où l'on procède par aspiration, les conduits verticaux venant d'un même trumeau débouchent, trois par trois, dans un même conduit horizontal, isolé des autres,

qui se rend directement dans une sorte de chambre à air, laquelle forme la base de la cheminée d'évacuation, construite en briques. Dans cette chambre et dans la cheminée sont placés des récipients où circule de l'eau chaude, qui, en échauffant l'air affluent, doit donner à l'aspiration le degré d'énergie nécessaire. Le grenier est clos, plafonné, et mis autant que possible à l'abri du refroidissement.

Dans les pavillons n$^{os}$ 2, 4 et 6, ventilés par insufflation, tous les conduits verticaux, venant d'une même face des pavillons, débouchent dans un conduit horizontal commun placé dans l'angle aigu formé par les longs pans du toit et par le sol du grenier. Ces deux conduits débouchent par deux canaux inclinés à la base de la cheminée d'évacuation, qui est en zinc et qui ne reçoit aucun appareil propre à activer l'évacuation, pour laquelle, dans ce système, on a exclusivement compté sur l'action de l'appareil d'insufflation.

Cette dernière disposition est évidemment moins convenable que la première : les conduits horizontaux, communs à tous les canaux d'évacuation verticaux d'une même face, sont bien plus exposés au refroidissement que ceux des autres pavillons; s'il s'y fait quelques fissures, ce qui arrive toujours avec le temps, il est difficile de s'en apercevoir et de les réparer; ils peuvent faciliter la communication des conduits d'évacuation des lits d'une même salle avec ceux des diverses salles, et servir à des rentrées d'air vicié d'un étage à l'autre, ainsi que cela arrive quelquefois dans ce système, comme on le verra plus loin. Enfin, la cheminée en zinc, qui n'est pas préservée contre le refroidissement par une chemise de briques, permet en hiver un abaissement très-notable de la température de l'air vicié évacué, ce qui nuit beaucoup à l'activité de l'évacuation.

Ces défauts, dont le dernier est la conséquence de l'excessive confiance que les auteurs du système avaient dans l'énergie de l'action du ventilateur, peuvent être corrigés; mais dans l'état actuel, ils nuisent à la marche de l'évacuation.

Nous ne nous étendrons pas davantage, pour le moment, sur la description des appareils dont il s'agit de discuter les effets, et nous nous bornerons à ce qui concerne l'évacuation de l'air vicié, nous proposant d'en comparer les effets sous les rapports de l'énergie, de la régularité et de la stabilité.

### VENTILATION D'HIVER.

Dans cette saison, où la température de l'air extérieur est basse, tandis que celle des salles est maintenue à 16° dans les pavillons ventilés par aspiration, et à 18° ou 19° dans ceux qui le sont par insufflation, l'évacuation de l'air vicié se fait à peu près régulièrement par tous les conduits, dans l'un comme dans l'autre système; c'est ce qui résulte des expériences comparatives, exécutées par MM. E. Trélat et par H. Péligot[1] : les volumes d'air vicié évacués atteignent et dépassent souvent alors la proportion de 60 mètres cubes par heure et par lit[2].

Mais il n'en est pas à beaucoup près de même au printemps et à l'automne, quand il fait du vent, et encore moins en été, lorsque le chauffage étant faible ou nul, la température extérieure s'élève et se rapproche de celle de l'air des salles : alors, et surtout quand il fait du vent, se manifeste toute l'infériorité du système de l'insufflation, et au contraire toute la supériorité de celui de l'aspiration.

Sans entrer dans une discussion détaillée des résultats des nombreuses expériences exécutées à diverses époques par différents observateurs[3], nous les résumerons rapidement.

### VENTILATION PAR INSUFFLATION. — INFLUENCE DES TEMPÉRATURES.

Lorsque la température extérieure se rapproche de celle des salles, le volume d'air évacué par heure et par lit dans les pavillons n$^{os}$ 2, 4 et 6, ventilés par insufflation, s'abaisse à trente

1. *Etudes sur la ventilation*, 1$^{er}$ vol., page 385, *Insufflation.*

2. *Études sur la ventilation*, 1$^{er}$ vol., page 453, *Aspiration.*

3. Une partie des expériences dont il est ici question ont été faites, par mes soins, le 31 août 1863, au pavillon n° 4 de l'hôpital Lariboisière. Elles ont donné les résultats suivants :

| TEMPÉRATURE extérieure. | TEMPÉRATURE dans la cheminée. | DIFFÉRENCE de la température dans la cheminée et de la température extérieure. | TEMPÉRATURE dans les salles. | VOLUME d'air total évacué par heure. | VOLUME d'air évacué par heure et par lit. |
|---|---|---|---|---|---|
| — | — | — | — | — | — |
| 16° | 22° | 6° | 22°.50 | 3215$^{mc}$ | 31$^{mc}$.52 |

*Études sur la ventilation*, p. 420, 1$^{er}$ volume.

L'on remarquera que la température des salles était de 22°.50, alors que celle

et quelques mètres cubes, tandis que le même jour le volume évacué par heure et par lit dans les pavillons n$^{os}$ 1, 3 et 5, ventilés par aspiration [1], s'est élevé en moyenne à 82 mètres cubes.

de l'air extérieur n'était que de 16°, ce qui montre combien la ventilation de ces pavillons est insuffisante.

Si la température extérieure avait été plus élevée, il est évident que le volume d'air évacué par heure et par lit aurait été encore moindre.

D'autres expériences exécutées en avril et mai par MM. Leblanc, repétiteur de physique à l'École polytechnique, et Ser, ingénieur de l'assistance publique, ont fourni les résultats suivants :

| DATES | TEMPÉRATURE extérieure. | TEMPÉRATURE intérieure de la cheminée. | EXCÈS de la température de la cheminée sur la température extérieure. | VOLUME d'air total évacué par la cheminée par heure. | VOLUME d'air évacué par heure et par lit. |
|---|---|---|---|---|---|
| 29 mars. . | 15°.0 | 17°.0 | 2°.0 | 3046$^{\text{mc}}$ | 29$^{\text{mc}}$.86 |
| 11 avril. . | 13 5 | 14 5 | 1 0 | 3250 | 31 80 |
| 2 mai.. . | 14 9 | 17 0 | 2 1 | 2975 | 29 19 |
| 9 mai.. . | 15 0 | 15 4 | 0 4 | 3700 | 36 27 |
| | | Moyenne. . . . . | | 3243$^{\text{mc}}$ | 31$^{\text{mc}}$.79 |

*Etudes sur la ventilation*, p. 387. A. M.

1. Les expériences d'été sur les pavillons 1, 3, 5, ventilés par aspiration, ont été faites d'abord par M. Guérin, ingénieur de la maison L. Duvoir, au mois d'août 1861, et ont été répétées quinze jours de suite, du 5 au 22 inclusivement, principalement pendant les nuits, attendu que pendant le jour les portes étaient constamment ouvertes. Elles ont été répétées et vérifiées le 31 août par les soins de la direction du Conservatoire.

Les résultats moyens de ces expériences sont résumés dans le tableau suivant :

*Expériences sur la ventilation d'été dans les pavillons de l'hôpital Lariboisière, ventilés par appel, exécutées par M. Guérin, ingénieur de la maison L. Duvoir-Leblanc.*

| TEMPÉRATURE EXTÉRIEURE. | PAVILLON N° 1. Température intérieure de la cheminée. | PAVILLON N° 1. Excès de la température de la cheminée sur la température extérieure. | PAVILLON N° 1. Volume d'air total évacué par heure. | PAVILLON N° 3. Température intérieure de la cheminée. | PAVILLON N° 3. Excès de la température de la cheminée sur la température extérieure. | PAVILLON N° 3. Volume d'air total évacué par heure. | PAVILLON N° 5. Température intérieure de la cheminée. | PAVILLON N° 5. Excès de la température de la cheminée sur la température extérieure. | PAVILLON N° 5. Volume d'air total évacué par heure. |
|---|---|---|---|---|---|---|---|---|---|
| 18°.3 | 38°.1 | 19°.2 | 7980$^{\text{mc}}$ | 41°.2 | 22°.9 | 6912$^{\text{mc}}$ | 40°.9 | 22°.6 | 9136$^{\text{mc}}$ |
| Volume évacué par heure et par lit. . . . . . . | | | 78$^{\text{mc}}$.23 | | | 67$^{\text{mc}}$.76 | | | 89$^{\text{mc}}$.57 |

Volume d'air moyen évacué par heure et par lit. . . . 78$^{\text{mc}}$.52

### INFLUENCE DU VENTILATEUR SUR L'ÉVACUATION DE L'AIR VICIÉ.

Cette différence, si considérable entre la ventilation d'hiver et celle d'été, dans les pavillons ventilés par insufflation, vient de ce que pendant l'hiver l'action naturelle de l'excès de la température de l'air vicié évacué sur la température extérieure de l'air a, pour activer l'évacuation, une influence bien plus considérable que le ventilateur.

Des expériences répétées à sept reprises différentes, en décembre 1860 et en janvier 1861, alors que la température dans les salles était de 18° à 20° et celle de l'air extérieur comprise entre — 2° et + 4°, ont en effet montré que la part du ventilateur dans l'évacuation de l'air vicié n'était que d'environ 0,15 du tout, celle de l'aspiration naturelle étant de 0,85 [1].

On conçoit dès lors que, l'action de cette dernière cause natu-

*Expériences de vérification faites le 31 août par le Conservatoire.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16°.0 | 37°.0 | 21°.0 | 8071$^{mc}$ | 39°.0 | 23°.0 | 7996$^{mc}$ | 36°.0 | 20°.0 | 9175$^{mc}$ |
| Volume d'air évacué par heure et par lit. . ... | | | | 79$^{mc}$.12 | | | 78$^{mc}$.37 | | | 89$^{mc}$.95 |

Volume d'air moyen évacué par heure et par lit. . . . 82$^{mc}$.48

*Etudes sur la ventilation*, 1$^{er}$ volume, p. 468.

Ces résultats comparatifs d'expériences faites sur les pavillons ventilés par insufflation et sur ceux qui le sont par appel, montrent d'une manière évidente la supériorité de ce dernier mode pour assurer en toute saison l'évacuation d'un volume d'air suffisant, pourvu que la température dans la cheminée d'évacuation surpasse de 20° environ celle de l'air extérieur.

Nous ajouterons que les dispositions adoptées par M. L. Duvoir, pour la ventilation par appel, ne sont pas irréprochables et qu'elles seraient susceptibles de plusieurs améliorations importantes et faciles à réaliser, et qui ont été indiquées, dès 1860, à l'administration de l'Assistance publique. A. M.

1. Pour déterminer cette part proportionnelle du ventilateur dans l'évacuation de l'air vicié on a, le 13 et 16 décembre 1860 et le 10, 11 et 14 janvier 1861, observé les volumes d'air évacués par la cheminée générale quand le ventilateur marchait et quand il était arrêté. Dans le premier cas, le résultat obtenu était dû à l'action simultanée de ce ventilateur et de l'aspiration; dans le second, il ne dépendait que de l'aspiration seule déterminée par l'excès de la température dans la cheminée sur la température extérieure.

*Résultats des expériences sur l'influence du ventilateur de l'hôpital Lariboisière sur la ventilation générale du pavillon n° 4.*

| DATES. | CIRCONSTANCES DE L'EXPÉRIENCE. | VITESSE de l'air en 1''. | VOLUME D'AIR éventé en 1''. | VOLUME D'AIR éventé en 1 h. | DIFFÉRENCE de volume due au ventilateur. | PART proportionnelle dans l'effet total. Ventilateur. | PART proportionnelle dans l'effet total. Ventilation due à la chaleur. | TEMPÉRATURES extérieure. | TEMPÉRATURES dans la cheminée. | TEMPÉRATURES dans les salles. | Volume d'air de ventilation générale par heure et par lit, avec le ventilateur. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m. | m.c. | m.c. | m.c. | | | 0 | | 0 | m.c. |
| 13 décem. 1860. | Avec le ventilateur. 70 tours de la machine | C 1,20 R 1,29 | 1,531 | 5,512 | 732 | 0,133 | 0,867 | + 6 | 13 | 18 à 20 | 52,00 |
| | Sans ventilateur | C 1,19 R 1,07 | 1,328 | 4,780 | | | | | | | |
| 15 décem. 1860. | Avec le ventilateur. 72 tours de la machine | C 1,33 R 1,25 | 1,534 | 5,522 | 687 | 0,124 | 0,876 | + 3 à + 4 | 12 | 18 à 20 | 52,09 |
| | Sans ventilateur | C 1,18 R 1,09 | 1,343 | 4,835 | | | | | | | |
| 10 janvier 1861. | Avec le ventilateur. 74 tours de la machine. | 1,56 | 1,882 | 6,768 | 1,216 | 0,178 | 0,822 | — 3 | 9 | 19 | 63,85 |
| | Sans ventilateur | 1,28 | 1,545 | 5,552 | | | | | | | |
| | Avec le ventilateur. | 1,49 | 1,798 | 6,473 | 1,440 | 0,220 | 0,780 | — 3 | 9 | 19 | 60,94 |
| | Sans ventilateur | 1,16 | 1,400 | 5,040 | | | | | | | |
| 12 janvier | Avec le ventilateur. 78 tours de la machine. | 1,61 | 1,943 | 6,994 | 1,126 | 0,161 | 0,839 | — 3 | 10 à 9 | 19 | 65,88 |
| | Sans ventilateur | 1,35 | 1,629 | 5,863 | | | | | | | |
| 14 janvier | Avec le ventilateur. 60 tours de la machine. | 1,42 | 1,714 | 6,170 | 651 | 0,106 | 0,894 | — 2 | 10 | 19 | 58,15 |
| | Sans ventilateur | 1,27 | 1,532 | 5,519 | | | | | | | |
| | Avec le ventilateur. 68 tours de la machine. | 1,45 | 1,750 | 6,300 | 781 | 0,124 | 0,876 | — 2 | 9 | 19 | 59,43 |
| | Sans ventilateur | 1,27 | 1,533 | 5,519 | | | | | | | |

NOTA. — Les nombres de tours indiqués sont ceux de la machine à vapeur. Le ventilateur marchait quatre fois plus vite.

1. Dans les expériences des 13 et 15 décembre 1860, pour s'assurer si l'on pouvait se contenter de mesurer la vitesse de l'air au centre de la cheminée, ou s'il fallait l'observer en plusieurs points pour en déduire une valeur moyenne d'une exactitude suffisante, on a fait des observations successives au centre et à une distance de la paroi égale à un quart du rayon. Les résultats particuliers de ces observations sont indiqués à la colonne des vitesses par les lettres C et R.

2. Expériences faites avec le concours de M. Trélat, professeur de constructions civiles au Conservatoire des arts et métiers.

3. Expérience répétée en présence de la commission chargée d'examiner les projets de chauffage et de ventilation pour les nouveaux théâtres de la place du Châtelet.

relle diminuant à mesure que la température de l'air extérieur s'élève, l'effet total doit suivre la même marche.

L'expérience montrant d'ailleurs la très-faible influence de ventilateur sur l'évacuation de l'air, on voit qu'en réalité cette évacuation ne se produit, pour la plus grande partie, que par l'effet de l'aspiration naturelle, et que la plus ou moins grande vitesse donnée au ventilateur ne saurait remédier à l'insuffisance de la ventilation de printemps et d'été.

A l'inverse, dans les pavillons nos 1, 3 et 5, ventilés par aspiration, la disposition des appareils et les proportions qui leur ont été données pouvant permettre en toute saison de maintenir dans la cheminée générale d'évacuation une température qui excède d'une quantité constante de 20° à 25°, par exemple, la température extérieure, la vitesse d'évacuation et, par conséquent, le volume d'air vicié extrait des salles peuvent, en tout temps, rester les mêmes.

C'est ce que confirment complétement les observations faites au printemps et en été[1].

Il résulte donc de là cette première conséquence que les dispositifs qui procèdent par insufflation n'ont sur l'évacuation régulière de l'air vicié qu'une faible influence, et qu'ils ne lui donnent pas en toute saison l'énergie nécessaire.

### INFLUENCE DE L'OUVERTURE DES PORTES ET DES FENÊTRES.

Dans le système de l'insufflation, l'appel exercé par la cheminée générale d'évacuation n'ayant souvent qu'une très-faible

Ces résultats obtenus et répétés, en présence de partisans du système de l'insufflation, montrent d'une manière évidente la part considérable de l'aspiration naturelle dans l'évacuation de l'air, et la très-faible influence du ventilateur sur l'effet obtenu.

Or, l'été l'action du ventilateur reste la même que l'hiver, tandis que dans ces pavillons la cheminée d'évacuation n'étant pas chauffée artificiellement, l'excès de sa température intérieure sur celle de l'air extérieur se trouvant très-diminué ou même presque annulé, le concours de la ventilation naturelle est réduit à fort peu de chose, ce qui explique comment, dans les saisons de printemps, d'été et d'automne, l'évacuation de l'air vicié devient tout à fait insuffisante. A. M.

1. *Études sur la ventilation*, 1er vol., page 464, pour les expériences où l'excès de température a été de 20° à 25°, et 1er vol., page 468.

énergie, il en résulte qu'au printemps et en été l'ouverture des portes ou des fenêtres permet à l'air nouveau de s'échapper directement par ces orifices, au lieu de se diriger vers les orifices d'évacuation; et dès lors l'air vicié n'est plus extrait des salles avec l'uniformité nécessaire à leur assainissement.

Mais, en outre, il se produit souvent un effet bien plus fâcheux : ce sont des rentrées d'air vicié qui, par suite du mouvement d'entraînement déterminé par le courant d'air nouveau vers les portes ou les fenêtres ouvertes, redescend des conduits d'évacuation des trumeaux, et peut ainsi passer d'une des salles supérieures dans les salles inférieures qui, au lieu d'être assainies, se trouvent de nouveau infectées.

Ces effets ont été constatés de la manière la plus nette dès 1856, au mois d'avril, par MM. E. Trélat et H. Péligot[1], et consignés dans un rapport adressé par eux à l'administration. Ils ont

1. Les expériences de M. E. Trélat et H. Péligot ont donné les résultats comparatifs suivants, le 7 avril 1856. Elles ont été faites sur six orifices, placés deux à deux vis-à-vis l'un de l'autre, sur les faces nord et sud du pavillon n° 4 de l'hôpital Lariboisière.

*Volumes d'air évacués par heure par les orifices de la salle du 1er étage.*

| ORIFICE N° 1. | | ORIFICE N° 5. | | ORIFICE N° 9. | | VOLUME d'air moyen évacué par orifice et par heure. |
|---|---|---|---|---|---|---|
| NORD. | SUD. | NORD. | SUD. | NORD. | SUD. | |
| *Les portes et les fenêtres étant fermées.* | | | | | | |
| mc. 115.00 | mc. 118.00 | mc. 112.00 | mc. 106.00 | mc. 104.00 | mc. 122.00 | mc. 113.00 |
| *La 5e fenêtre nord étant ouverte.* | | | | | | |
| (*) 52.19 | 82.94 | (*) 99.39 | 50.05 | (*) 77.94 | 45.49 | 68.00 |
| *La 4e fenêtre nord et la 5e sud étant ouvertes.* | | | | | | |
| (*) 61.42 | 33.70 | (*) 32.37 | 55.61 | 33.37 | 21.08 | 39.42 |
| *Les 4e et 5e fenêtres de chaque côté étant ouvertes.* | | | | | | |
| (*) 16.65<br>(*) 0.93 | (*) 38.30<br>22.50 | (*) 62.90<br>(*) 3.14 | (*) 36.07<br>14.40 | 16.10<br>54.40 | (*) 20.16<br>34.20 | 31.37<br>20.17 |

Les signes (*) placés à gauche des volumes d'air évacués indiquent qu'il y a eu souvent des arrêts dans la marche de la ventilation. Les chiffres soulignés indiquent qu'il y a eu non-seulement arrêt, mais refoulement et rentrée d'air vicié venant des autres étages. L'on voit que, sur les six orifices soumis aux expé-

reconnu que l'ouverture d'une ou de deux fenêtres déterminait des arrêts complets dans l'évacuation de l'air vicié dans les conduits, et que celle de quatre fenêtres occasionnait des rentrées d'air vicié par quatre conduits sur six, et des arrêts dans les deux autres.

Il résulte donc de ces expériences que, *dans le système exclusif de l'insufflation, l'ouverture des portes et des fenêtres trouble, de la manière la plus grave, l'évacuation de l'air vicié, et, comme cette ouverture est, dans la belle saison, une jouissance dont on ne peut songer à priver les malades, et même trop souvent une nécessité, les faits précédents constituent un défaut sérieux auquel ce système, tel qu'il a été conçu et exécuté, ne peut échapper.*

A l'inverse, l'observation[1] montre que, dans le système de l'aspiration, l'ouverture des portes et des fenêtres, au lieu de troubler et de diminuer l'évacuation, tend à la régulariser pour tous

riences, il y en a eu quatre ou les deux tiers pour lesquels cet effet s'est produit, quand, sur les seize fenêtres qui existent dans les salles, il y en avait seulement quatre d'ouvertes, ce qui naturellement arrive fréquemment l'été.

Les conséquences que MM. E. Trélat et H. Péligot ont tirées de ces expériences, et qui sont relatées ci-dessus, sont graves, et l'un des partisans les plus persévérants du système de l'insufflation disait, en parlant de ces rentrées d'air vicié : « Si le fait existait réellement, il faudrait renoncer au système, car il est « impossible d'éviter l'ouverture très-fréquente des portes et quelquefois des « fenêtres. »

Or le fait existe, il n'est pas contesté; et cependant le même observateur n'a pas hésité depuis à persévérer dans l'opinion favorable qu'il avait émise sur le système de l'insufflation et à approuver un autre dispositif analogue, mais bien inférieur à celui de l'hôpital Lariboisière. L'on peut donc s'étonner à bon droit de la préférence que, dans des publications assez récentes, l'administration de l'Assistance publique a cru pouvoir accorder aux dispositifs qui procèdent exclusivement par l'insufflation. Il y a lieu de penser que, mieux éclairée par les discussions qui se sont produites dans le sein du Comité consultatif d'hygiène et du service médical des hôpitaux, cette administration ne persistera pas dans cette opinion. A. M.

1. Les expériences dont il est ici question ont été faites, en 1856, par MM. E. Trélat et H. Péligot, et elles sont consignées dans un rapport adressé à cette époque à l'administration de l'Assistance publique. Elles ont eu pour objet de reconnaître quelle est, dans les systèmes qui procèdent simplement par aspiration, l'influence de l'ouverture des portes et des fenêtres.

Les résultats suivants des expériences faites par un temps de pluie et de grand

les conduits, et augmente parfois le volume de l'air vicié extrait des salles dans une proportion supérieure au double de sa valeur première.

De cette comparaison, il résulte donc que le système de l'aspiration présente, sous les rapports de la régularité, de l'énergie et de la stabilité de l'évacuation de l'air vicié, une supériorité incontestable sur le système exclusif de l'insufflation, tel qu'il est organisé à l'hôpital Lariboisière; cette supériorité ne provient d'ailleurs que de ce que le dispositif adopté pour produire en tous temps une aspiration énergique permet, comme le pres-

vent ont manifesté l'influence de la simple ouverture des portes sur l'activité de l'évacuation de l'air par tous les orifices d'appel d'une même salle, au nombre de neuf sur chaque face.

*Volume d'air sortant par heure par les orifices d'évacuation d'une salle du pavillon n° 3, ventilé par appel.*

| NUMÉROS des ORIFICES. | COTÉ SUD. Volume d'air sortant quand la porte était | | COTÉ NORD. Volume d'air sortant quand la porte était | |
|---|---|---|---|---|
| | FERMÉE. | OUVERTE. | FERMÉE. | OUVERTE. |
| | mc. | mc. | mc. | mc. |
| 1 | 115.44 | 420.65 | 94.25 | 430.10 |
| 2 | 56.55 | 346.50 | 92.00 | 318.92 |
| 3 | 29.25 | 346.00 | 0.74 (*) | 306.00 |
| 4 | 184.08 | 479.50 | 139.46 | 338.30 |
| 5 | 364.20 | 328.20 | 286.75 | 255.00 |
| 6 | 277.00 | 337.25 | 388.50 | 287.30 |
| 7 | 141.00 | 295.75 | 239.39 | 306.00 |
| 8 | 158.00 | 311.50 | 108.78 | 300.90 |
| 9 | 98.30 | 269.05 | 96.94 | 262.48 |
| Moyenne par orifice...... | 151.53 | 370.49 | 149.70 | 311.66 |

(*) L'orifice n° 3 du côté nord a évidemment fourni un résultat anormal quand la porte était fermée.

Les conséquences de ces expériences sont évidentes, il est inutile de les indiquer; et l'on voit que l'ouverture des portes diminue considérablement les inégalités qui se produisent dans l'évacuation de l'air par les différents conduits, et qu'en moyenne elle augmente le volume d'air évacué par la cheminée d'appel dans le rapport de 1.00 à 2.26.

L'influence de l'ouverture des fenêtres a une influence analogue, mais moins marquée, parce qu'alors une partie de l'évacuation se fait alors par la partie supé-

crit la théorie, d'obtenir dans la cheminée d'évacuation une température qui surpasse toujours de 20 à 25 degrés celle de l'air extérieur[1].

En hiver, quoique cette différence de température ne soit pas toujours dépassée, le volume d'air évacué s'élève à cent et à cent vingt-cinq mètres cubes par heure et par lit.

Il serait facile de mettre, sous ce rapport, les pavillons n$^{os}$ 2, 4, 6 de l'hôpital Lariboisière[2] dans des conditions aussi favo-

périeure de ces larges bancs. C'est ce que montrent les résultats suivants des expériences des mêmes observateurs :

PAVILLON N° 1.

*Volumes d'air évacués par l'orifice n° 2 en une heure.*

| | | |
|---|---|---|
| 1. | Toutes les portes et les fenêtres fermées. . . . | 116 mètres cubes. |
| 2. | Une fenêtre n° 2 adjacente ouverte. . . . . . | 169 — |
| 3. | Les deux fenêtres adjacentes ouvertes. . . . . | 170 — |
| 4. | Les deux fenêtres en face ouvertes.. . . . . . | 169 — |
| 5. | Les quatre fenêtres précédentes ouvertes. . . . | 163 — |
| 6. | Les deux fenêtres n° 4 ouvertes. . . . . . . . | 162 — |
| 7. | Les deux fenêtres du fond de la salle ouvertes. | 156 — |
| 8. | Toutes les portes et les fenêtres fermées. . . . | 118 — |

De l'ensemble de ces expériences il résulte donc que l'ouverture accidentelle ou permanente des portes ou des fenêtres, loin de troubler l'évacuation de l'air vicié dans le système de l'aspiration, l'active à un degré très-sensible, tandis que l'effet contraire se produit dans le système exclusif de l'insufflation.

Il s'ensuit que dans le jour, quand le temps est chaud, la simple ouverture des portes est un moyen d'activer et même de régulariser la ventilation par appel dans toute l'étendue des salles.

Quant à la ventilation de nuit, par les temps le plus chauds, où il convient cependant de tenir les portes fermées, on l'activerait beaucoup si l'on ménageait dans les salles des carneaux d'introduction de l'air analogues à ceux qui le conduisent aux poêles et qui, débouchant vers le plafond, fourniraient un supplément d'air considérable à la ventilation pour laquelle l'arrivée de l'air par les poêles, dans cette saison, n'est pas suffisante.

Cette amélioration, que nous avions indiquée dès 1860, n'est pas encore introduite, et l'on continue encore à attribuer au système de l'appel les conséquences des dispositions incomplètes adoptées par M. L. Duvoir des défauts que l'on aurait pu faire disparaître. A. M.

1. *Études sur la ventilation*. Expériences d'automne, page 442. Expériences de printemps, page 464. Expériences d'été, page 468.

2. *Études sur la ventilation*, 1$^{er}$ vol., page 462.

rables, pour l'évacuation de l'air vicié, que les pavillons n$^{os}$ 1, 3 et 5 : il suffirait pour cela, comme votre rapporteur l'avait indiqué, dès l'année 1860, dans le *Rapport de la Commission du chauffage et de la ventilation des nouveaux bâtiments du Palais de Justice*, de disposer à la partie inférieure de la cheminée d'évacuation de ces pavillons un appareil de chauffage à l'eau chaude ou à la vapeur. Mais, quoique cette amélioration facile soit désirable, il ne faut pas perdre de vue qu'elle accroîtrait la dépense, déjà bien considérable, faite par les appareils de ces pavillons : nous aurons d'ailleurs plus tard à revenir sur l'ensemble des perfectionnements à introduire dans les deux groupes de pavillons de cet hôpital.

### DES RENTRÉES D'AIR PRODUITES PAR L'ASPIRATION.

L'on reproche, et souvent non sans raison, aux ventilations qui procèdent par aspiration, de déterminer, par la rentrée de l'air, des courants fort désagréables.

Toutes les personnes qui ont assisté aux soirées du château des Tuileries, à celles de l'Hôtel-de-Ville, où l'évacuation de l'air chaud et vicié se fait par les plafonds, à travers des rosaces ménagées au-dessus des lustres, ont dû, en effet, observer l'intensité des courants d'air qui se produisent par les portes pour remplacer l'air vicié par les orifices supérieurs. Des effets analogues et aussi gênants s'observent dans tous les théâtres ventilés par des dispositions semblables.

Mais ces effets désagréables ne proviennent que de l'absence de dispositions convenables pour assurer la rentrée de l'air, de telle façon qu'il afflue le plus loin possible des personnes, avec une faible vitesse et une température peu différente de celle que l'on veut maintenir dans les salles[1].

A ces dispositions, toujours faciles à prendre, lors de la construction des édifices, il faut en joindre d'autres qui consistent à

1. Il convient d'ajouter à ce qui précède qu'un moyen efficace de diminuer encore, pendant l'hiver, l'inconvénient des courants d'air froid produits par l'ouverture des portes consiste à disposer dans l'intervalle des doubles portes une bouche de chaleur qui y maintienne toujours une température un peu supérieure à celle des salles. A. M.

chauffer tous les abords des salles, les vestibules, les escaliers, les antichambres qui y conduisent, à munir les entrées de doubles portes tombant d'elles-mêmes, de façon qu'à chaque ouverture de l'une d'elles, il n'entre dans les salles qu'un petit volume d'air à une température égale ou même un peu supérieure à celle de la salle.

Ce n'est pas ici le lieu d'indiquer les proportions des orifices spéciaux d'accès de l'air, il nous suffira de dire qu'ils doivent être aussi nombreux que possible, et que leur surface totale libre doit être telle que la vitesse de l'air affluant atteigne à peine en moyenne $0^m,50$ en une seconde s'il se peut.

Outre l'inconvénient de produire des courants d'air, les ventilations par appel, imparfaitement organisées, ont celui d'introduire parfois dans les salles des odeurs désagréables, telles que celles des cuisines, des lieux d'aisance, etc.; mais il est évident que cela ne tient qu'à ce que la ventilation particulière de ces dépendances n'a pas été convenablement assurée. C'est encore là une faute du constructeur et non un défaut du système[1].

L'exemple des amphithéâtres du Conservatoire des Arts et métiers, où ces précautions et ces dispositions ont été adoptées depuis deux ans, et où on n'éprouve l'impression d'aucun courant d'air gênant, quoique, dans l'un d'eux, il circule par fois 18000 mètres cubes d'air par heure, et que les portes y soient fréquemment ouvertes, prouve que l'inconvénient reproché à beaucoup de ventilations par aspiration n'est que la conséquence des mauvaises dispositions adoptées, et qu'il est facile de s'en préserver.

Il convient d'ailleurs d'ajouter, comme l'ont fait plusieurs observateurs, que, dans le système de l'insufflation, ces inconvénients se produisent aussi d'une manière très-sensible, attendu qu'en réalité l'évacuation de l'air vicié ne s'y fait, pour la plus grande partie, que par aspiration.

1. Le moyen le plus sûr d'éviter que les mauvaises odeurs des cuisines ou des lieux d'aisances ne se répandent à l'intérieur des bâtiments, c'est d'y déterminer, soit par des foyers, soit à l'aide de becs de gaz ou autres moyens de chauffage, un appel d'air qui y fasse affluer l'air extérieur et évacue l'air intérieur. Cela ne présente presque jamais de difficulté.

DU SYSTÈME DE VENTILATION PAR INSUFFLATION DU D[r] VAN HECKE.

Toutes les conséquences que nous avons déduites de la discussion des nombreuses expériences faites sur les appareils de ventilation par insufflation de l'hôpital Lariboisière[1], appareils bien exécutés dans leur genre, sous la direction d'ingénieurs habiles, sont *à fortiori* applicables à ceux que M. le docteur belge Van Hecke a cherché à introduire en France et qu'il a installés à Paris, à l'hôpital Beaujon, à l'hôpital Necker et au Vésinet, à l'Asile impérial de convalescence.

Les dispositions adoptées par ce constructeur pour l'extraction de l'air vicié sont défectueuses sous plus d'un rapport. Les conduits d'évacuation ne sont presque jamais assez nombreux, il n'y en a souvent qu'un ou deux par salle. Ils sont éloignés les uns des autres, débouchent tantôt au-dessus des toits, tantôt dans l'intérieur de greniers, et sont toujours exposés à l'action des vents qui refoulent dans les salles l'air vicié et même l'air froid extérieur d'une manière tellement incommode qu'il n'est pas rare de voir les orifices de ces conduits bouchés par les sœurs ou par les malades. Les témoignages recueillis par MM. Rayer et Pelouze, ainsi que par votre rapporteur à l'hôpital Necker, et par M. Laval avec le rapporteur, à l'asile du Vésinet, ne laissent aucun doute à cet égard.

Le ventilateur à palettes héliçoïdales adopté par M. le docteur Van Hecke était connu et abandonné depuis longtemps comme défectueux, et des expériences spéciales faites au Conservatoire des arts et métiers ont montré qu'il est inférieur à ceux qui sont en usage à l'hôpital Lariboisière.

Des expériences nombreuses faites par votre rapporteur en présence de M. Laval et du docteur Van Hecke, en janvier 1861, ont montré qu'à l'Asile impérial du Vésinet, l'action du ventilateur n'exerçait, quant à l'évacuation de l'air vicié, qu'une influence tout à fait insensible. En observant, en effet, les volumes d'air évacués par les 42 cheminées de 28 salles du pavillon F de cet hospice, l'on a obtenu des résultats[2] qui peuvent se résumer ainsi qu'il suit :

1. *Annales du Conservatoire*, n° 17, 186.
2. *Etudes sur la ventilation*, par A. Morin, 1[er] vol., pages 504-505.

*Pavillon F. — Aile gauche.*

1re Série. — Le ventilateur fonctionnant seul. Volume total évacué en 1″ = 1183 lit. 60 c.

2e Série. — L'aspiration fonctionnant seule. Volume total évacué en 1″ = 1253 lit. 39 c.

*Pavillon F. — Aile droite.*

1re Série. — Le ventilateur fonctionnant seul. Volume total évacué en 1″ = 1201 lit. 90 c.

2e Série. — L'aspiration fonctionnant seule. Volume total évacué en 1″ = 1137 lit. 54 c.

Des expériences analogues faites en avril et mai 1861 par MM. Leblanc et Ser à l'hôpital Necker[1], dans un pavillon ventilé par le même système, ont montré qu'à cette époque le ventilateur ne contribuait que pour 1/9 ou 1/10 à l'évacuation de l'air vicié, qui n'était ainsi due pour la plus grande partie qu'à l'aspiration naturelle.

### CONCLUSION RELATIVE A L'ÉVACUATION DE L'AIR VICIÉ.

De l'ensemble des résultats d'expériences dont la commission a pris connaissance et des discussions auxquelles elle s'est livrée, elle a déduit la conclusion que :

*Les divers dispositifs qui procèdent par aspiration, lorsqu'ils sont*

1. *Études sur la ventilation*, page 494. Expériences de MM. Leblanc et Ser.

Ces expériemnces ont indiqué qu'au printemps, alors que le chauffage était très-modéré et la température extérieure comprise entre 9°.3 et 13°.0, le volume d'air évacué des salles du pavillon ventilé par l'appareil d'insufflation du Dr Van-Hecke, étaient :

Par le concours de l'aspiration naturelle et du ventilateur . . 4195 mètr. cub. par heure ou 23mc.70 par lit.

Par l'action seule de l'aspiration . . . . . . . . . . . . . . 2697 —

En tenant compte de la différence des températures extérieures observées aux heures où ces expériences sont faites, le volume d'air évacué par l'action seule de l'aspiration devrait être augmenté dans le rapport de 1.00 à 0.79 et porté à 3415 mètres cubes, de sorte que la part du ventilateur, dans le résultat obtenu lorsqu'il fonctionnait, n'était que de 4195 — 3415 = 780 mètres cubes ou $\frac{780}{4195} = 0.185$ du volume total évacué. A. M.

*bien proportionnés, satisfont mieux et plus sûrement aux conditions d'uniformité et de stabilité de l'évacuation de l'air vicié, que ceux qui procèdent exclusivement par insufflation de l'air neuf.*

### INTRODUCTION DE L'AIR NOUVEAU.

Cette première et importante partie de la question de la ventilation étant résolue, il restait à examiner l'effet des différents systèmes au point de vue de l'introduction de l'air nouveau.

Dans celui de l'aspiration, cette entrée d'air est naturellement déterminée par l'excès de la pression de l'air extérieur sur celle de l'air intérieur que cette aspiration produit. Mais des dispositions et des proportions convenables sont nécessaires pour que l'appel, ainsi créé, soit suffisant et ne détermine pas de courants incommodes, ainsi que nous l'avons déjà dit.

La plupart des constructeurs qui ont établi des appareils de ventilation par appel ne se sont pas assez préoccupés des proportions qu'il est nécessaire d'adopter. Pour la saison d'hiver, ils ont pensé que l'activité donnée à l'introduction par la chaleur des poêles à eau ou à vapeur, à travers lesquels l'air nouveau pénétrait, serait assez grande pour assurer l'introduction de l'air en volume suffisant. Cela n'est à peu près vrai que pour cette saison, et l'expérience montre qu'il en est effet ainsi à l'hôpital Lariboisière, par exemple, où votre rapporteur a constaté, le 10 et le 11 janvier 1861, que[1], par des températures extérieures de — 5° et de — 2°, les poêles à eau chaude du pavillon n° 3, ventilé par appel, introduisaient dans les salles :

| ETAGES. | 10 JANVIER. | 11 JANVIER. |
|---|---|---|
| | mètres cubes. | mètres cubes. |
| Au rez-de-chaussée.................. | 2122 | 2005 |
| Au premier étage................ ... | 1911 | 1751 |
| Au deuxième étage.................. | 2097 | 2130 |
| Total.................. | 6130 | 5886 |
| Moyenne................ | 6008 mètres cubes. | |

1. *Etudes sur la ventilation*, par A. Morin, 1er vol., pages 459 et suivantes.

Il y a trente-deux lits dans chaque salle, ou quatre-vingt-seize en tout pour les trois salles. Par conséquent, le volume d'air introduit les 10 et 11 janvier 1861 était, en moyenne, de 62$^{mc}$.58 par heure et par lit.

Dans ces expériences, on a remarqué des différences considérables entre les volumes fournis par les différents poêles d'une même salle, et, comme ils ont tous les mêmes proportions, cela ne peut tenir qu'à quelque défaut dans le règlement des passages de l'air, ou à des obstructions accidentelles des conduits, ce qui devrait être vérifié de temps en temps [1]. Quoi qu'il en soit, l'on voit qu'abstraction faite de plusieurs dispositions défectueuses des appareils, ils peuvent, l'hiver, fournir un volume d'air de 60 mètres cubes au moins par heure et par lit, à une température modérée, qui varie de 30° à 35° environ.

Cet air chaud s'élève directement vers le plafond, comme on peut s'en assurer à l'aide de ballons légers; il s'étale en nappes horizontales, redescend et vient gagner les orifices d'appel placés entre les lits, produisant ainsi un renouvellement aussi uniforme que possible de l'air dans toute la salle. Comme il entre, en outre, une certaine quantité d'air par les joints des fenêtres et par ceux des portes, il en résulte évidemment que, même avec les proportions insuffisantes, selon nous, adoptées par le constructeur, la ventilation d'hiver est assurée quant à la rentrée de l'air nouveau aussi bien que pour l'évacuation.

Mais il ne faut pas perdre de vue que, dans cette saison, si l'introduction a lieu par les poêles plutôt que par les joints des portes et des fenêtres, c'est l'effet de l'échauffement de ces poêles qui y produit une aspiration partielle plus énergique encore que l'aspiration générale. Or, dès que la saison permet de diminuer l'intensité du chauffage par suite de l'élévation de la température extérieure, le volume d'air ainsi aspiré, qui est, comme on le sait, proportionnel à la racine carrée de l'excès de la tem-

1. Cette observation sur les défauts particuliers des conduits qui amènent l'air à certains poêles, ainsi que sur les inégalités des effets observés dans des pavillons où tout paraît, au contraire, semblable, a été faite dès 1860, et la nécessité d'y remédier par des modifications faciles, mais nécessaires, avait été indiquée. Jusqu'ici l'on ne s'en est pas occupé, et les partisans des appareils d'insufflation ont continué à attribuer au principe de l'aspiration des effets qui ne sont que le résultat de défauts de proportion ou d'entretien des appareils établis. A. M.

pérature dans les conduits du poêle sur celle de l'air extérieur, doit diminuer aussi, et, dès lors, les mêmes conduits n'offrent plus une section assez grande pour donner passage au volume d'air voulu.

C'est ce que montrent les expériences faites par plusieurs observateurs au printemps sur les mêmes appareils et, en particulier, celles de MM. E. Trélat et H. Péligot, faites en avril 1856[1], et celles de M. Grassi.

Ces observateurs en ont conclu, d'une manière générale, que le système de l'aspiration ne pouvait pas assurer convenablement l'introduction de l'air. Mais, si cela est vrai pour les appareils établis par M. L. Duvoir à l'hôpital Lariboisière, ce défaut ne tient qu'à l'insuffisance des proportions des passages et non pas au système lui-même. On en trouve la preuve dans les expériences de M. Trélat; car on y voit manifestée une très-grande irrégularité dans les volumes fournis, le 9 avril 1856, par des poêles des mêmes salles, qui, disposés d'une manière en apparence identique, ont donné, les uns 562$^{mc}$.90, — 530$^{mc}$.00, — 611$^{mc}$.10, — 498$^{mc}$.00, — 567$^{mc}$.00, — 442$^{mc}$.00 par heure, et les autres seulement 176$^{mc}$.00, — 220$^{mc}$.00, — 96$^{mc}$.60, — 112$^{mc}$.90, — 137$^{mc}$.50, etc. Ces différences indiquent des défauts de proportion, des obstructions partielles, qui ne sauraient être imputés au principe même du système.

Si tous les poêles avaient des conduits de prise d'air suffisants, aussi libres et aussi bien disposés que les premiers, dont nous venons d'indiquer le produit en air nouveau, le volume d'air introduit pourrait même, au printemps ou à l'automne, s'élever à 60 et 70 mètres cubes par heure et par lit.

Mais, dans l'été, il en serait sans doute autrement. Or, rien ne s'oppose à ce que, d'une part, on emploie des poêles présentant des passages plus larges et d'un accès plus facile, et, de l'autre, qu'on ménage des orifices auxiliaires de prise d'air pour cette saison. Votre rapporteur avait indiqué, dès 1860, ce genre d'amélioration facile à réaliser, dans le *Rapport sur le chauffage et la ventilation des nouveaux bâtiments du Palais de Justice*, page 80. On lit, en effet, dans ce rapport : « Bien que la ventilation de-

1. *Etudes sur la ventilation*, par A. Morin. Expériences de MM. E. Trélat et H. Péligot, 1er vol., page 448.

« mandée par les conditions du marché (60 mètres par heure et « par lit) soit obtenue et même dépassée avec ces appareils (de « M. L. Duvoir), et que la ventilation de jour, pendant l'été, « puisse être doublée par la seule ouverture des portes ou de « quelques fenêtres, nous pensons que, pour les nuits d'été sur- « tout, une ventilation plus abondante est nécessaire. Mais « comme pendant la nuit il ne convient pas d'ouvrir les portes « et encore moins les fenêtres, il faut ménager des carnaux spé- « ciaux d'arrivée de l'air extérieur qui, à cette époque de l'année, « n'aurait pas besoin d'être chauffé. »

Si nous nous sommes étendus longuement sur les résultats observés dans les pavillons de l'hôpital Lariboisière, c'est qu'ils ont servi de texte aux critiques qui ont été adressées au principe de la ventilation par appel, et que, de ces résultats particuliers, l'on a conclu, fort à tort selon nous, que ce système n'assurait pas convenablement la rentrée de l'air nouveau, tandis que l'ensemble de ces mêmes observations devait porter seulement à conclure que certaines proportions des appareils, certaines dispositions étaient insuffisantes ou défectueuses, et qu'en les modifiant on arriverait à des résultats satisfaisants en tous temps.

L'exemple des dispositions adoptées avec succès au Conservatoire des arts et métiers prouve que l'aspiration exercée pour l'extraction de l'air vicié suffit pour assurer, d'une manière convenable, la rentrée de l'air nouveau, pourvu que l'on ménage, pour cette rentrée, des orifices d'un accès facile, d'une étendue libre assez grande pour que la vitesse d'arrivée n'excède pas, s'il se peut, 0m.50 en 1″ et situés le plus loin possible des personnes.

Nous avons vu déjà plus haut quels sont les moyens d'éviter ou d'atténuer les courants d'air résultant des ouvertures des portes, et nous nous bornerons ici à dire que, plus les orifices réguliers d'admission de l'air seront nombreux, grands et uniformément répartis, plus ces courants seront faibles et insensibles.

Nous ne parlerons pas de quelques autres dispositifs adoptés dans les hôpitaux ou dans des établissements ventilés par appel, parce que nous nous occupons surtout, dans ce rapport, de poser les principes qui doivent guider les ingénieurs dans l'étude

de leurs projets, et nous allons examiner les résultats fournis par les appareils d'insufflation sous le rapport de l'introduction de l'air nouveau.

### INTRODUCTION DE L'AIR NOUVEAU PAR LES APPAREILS D'INSUFFLATION.

Nous prendrons encore pour terme de comparaison l'installation faite d'un système de ce genre à l'hôpital Lariboisière par d'habiles ingénieurs, qui n'ont rien négligé pour en assurer le succès.

On sait que, dans les pavillons n$^{os}$ 2, 4 et 6 de cet hôpital, l'air nouveau doit être refoulé dans les salles à l'aide d'un ventilateur placé dans les caves et mis en mouvement par une machine à vapeur de la force de sept à huit chevaux.

### PRISE D'AIR A UNE CERTAINE HAUTEUR AU-DESSUS DU SOL.

Cet air, aspiré par le ventilateur, afflue dans la chambre, qui contient cet appareil ainsi que la machine à vapeur, par une cheminée ménagée dans le clocher de la chapelle, et est ainsi puisé à une assez grande hauteur au-dessus du sol.

L'on espérait, par cette disposition, l'obtenir plus pur, et l'on se flattait même que l'été il serait plus frais que de l'air pris à une moindre hauteur. Mais, d'une part, il est difficile dans l'état actuel d'empêcher qu'une partie de l'air aspiré par le ventilateur ne lui soit fournie par les pièces voisines de la chambre qui le contient, même quand les portes sont fermées et à plus forte raison quand elles sont ouvertes. C'est ce qu'ont montré les expériences de M. Grassi [1], aussi bien que celles de MM. E. Trélat et H. Péligot [2]. Le premier a trouvé que, quand toutes les portes sont fermées, le rapport du volume d'air fourni au ventilateur par la cheminée d'appel au volume d'air total

1. *Etudes sur la ventilation*, par A. Morin, 1$^{er}$ vol., pages 359 et suivantes.

2. *Etudes sur la ventilation*, pages 361 et suivantes.

M. Grassi, dans les *Annales d'hygiène*, tome VI, page 221, résume ainsi qu'il suit les résultats de ses observations :

« Toutes les portes et les fenêtres de la chambre des machines étant fermées, le volume de l'air qui passe par le tuyau porte-vent ou artère principale étant repré-

débité par l'appareil n'était que de 0,562. M. E. Trélat a obtenu, pour le même rapport, 0,63. La proportion devient beaucoup plus faible et descend à 0,23 et à 0,34 quand il y a des portes ouvertes, ce qui arrive nécessairement assez souvent.

Par conséquent, l'air aspiré par la cheminée de prise est toujours, dans le ventilateur, mélangé avec une proportion plus ou

senté par 1.00, celui qui arrive par la cheminée d'appel est 0.562, celui qui arrive par les ouvertures accidentelles ou venant des caves est 0.438.

« La porte n° 1 étant seule ouverte, le volume qui passe par la cheminée n'est plus que 0.229, et celui qui vient des caves est 0.771 du volume total. »

L'auteur en conclut que tout l'air qui circule dans le tuyau porte-vent et qui est envoyé aux salles n'est pas pris intégralement à la partie supérieure du clocher et que près de la moitié est puisée directement dans les caves en se plaçant dans les circonstances les plus favorables, c'est-à-dire quand toutes les portes sont fermées.

Par des observations analogues, MM. E. Trélat et H. Péligot ont trouvé des résultats qui les ont conduits aux conclusions suivantes :

1° Toutes les portes et les fenêtres étant fermées, l'air qui arrive par la cheminée est les 0 63 de celui qui est envoyé par le ventilateur dans le conduit principal; l'air fourni par les ouvertures accidentelles en est les 0.37.

2° La porte n° 1 des chaudières étant ouverte, l'air qui arrive par la cheminée est les. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.34

L'air qui est fourni par les ouvertures accidentelles est les. . . . . . . 0.66

Du tout. . . . . . . . . . . . . . . . 1.00

3° La porte de la communauté n° 2 étant ouverte, l'air qui arrive par la cheminée est les. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.43

L'air fourni par les ouvertures accidentelles est les. . . . . . . . . . 0.57

Du tout. . . . . . . . . . . . . . . . 1.00

4° Les deux portes étant ouvertes, l'air qui arrive par la cheminée est les. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.245

Et celui qui afflue par les ouvertures accidentelles est les. . . . . . . 0.755

Du tout. . . . . . . . . . . . . . . 1.000

L'on est parvenu, dans ces derniers temps, à éviter l'introduction de l'air des caves dans le ventilateur en établissant de la base de la cheminée aux orifices centraux de cet appareil un conduit direct qui interdit toute communication avec l'air de la chambre des machines. Cette disposition assez difficile à réaliser pourra en effet éviter l'inconvénient signalé, mais elle aura pour conséquence d'augmenter un peu la consommation de force motrice, et ne fera pas disparaître l'inconvénient grave pendant l'été et inhérent à l'emploi des ventilateurs d'augmenter la température de l'air, et dont il sera parlé dans une note suivante. A. M.

moins grande d'air moins pur venant des caves et de la chambre des machines.

D'une autre part, l'été, cet air puisé à 25 mètres environ au-dessus du sol, loin d'être, comme on l'a prétendu, plus frais que celui qui serait pris à quelques mètres seulement, est, au contraire, plus chaud; il s'échauffe encore nécessairement en passant dans la chambre des machines, et par le ventilateur[1]. Ce dernier résultat a été constaté, le 14 avril 1856, par MM. E. Trélat et H. Péligot, qui ont trouvé que, l'air étant à la base de la cheminée du clocher à la température de 14°, celui qui sortait du ventilateur était à 19°.

De même, le 22 août 1861, nous avons observé que, la température extérieure au nord et près du sol, à côté de la chapelle, étant de 21°,50, celle de l'air affluent par la cheminée était de 22°, et celle de l'air affluent dans les salles, de 24°.

Ainsi, non-seulement l'air fourni par cette prise d'air élevée, après avoir passé par le ventilateur, est toujours mélangé d'une proportion considérable d'air puisé dans les caves fréquentées par des ouvriers, mais encore, l'été, il est plus chaud que celui qui serait pris à quelques mètres au-dessus du sol[2].

1. *Études sur la ventilation*, par A. Morin, 1er vol., page 147.

M. Becquerel père, dans ses recherches récentes faites avec le thermomètre électrique, a obtenu les résultats suivants :

| MOIS DE 1860-1861. | TEMPÉRATURE MOYENNE DE L'AIR au nord à l'abri de la radiation solaire. | à 16m au-dessus du sol à la radiation solaire. | à 21m au-dessus du sol à la surface d'un gros arbre. |
|---|---|---|---|
| Juin, — Juillet, — Août. ........ | 17° .71 | 17° .85 | 17° .97 |
| Septembre, — Octobre, — Novembre. | 11 .14 | 12 .02 | 12 .18 |
| Décembre, — Janvier, — Février. .. | 3 .26 | 3 .45 | 3 .66 |

Des observations directes, faites le 22 août, à 4 heures 30 minutes de l'après-midi, ont indiqué les températures suivantes, à l'hôpital même de Lariboisière :

A l'extérieur, au nord, près de la chapelle. . . . . 21°.50
Sous les voûtes du sommet de la tour. . . . . . . 22°.00
Au bas de la cheminée à son débouché. . . . . . . 22°.00
A l'arrivée de l'air dans les salles. . . . . . . . . 24°.00

2. Mais outre l'erreur de physique commise au sujet des prises d'air à une

Les avantages attribués à ce mode de prise d'air, que l'on croyait exclusivement réalisable par l'emploi d'appareils mécaniques d'insufflation, ne sont donc pas aussi complétement obtenus qu'on le pensait; mais il convient, en outre, d'ajouter que le système de ventilation par appel permet tout aussi bien de puiser l'air nouveau dans l'atmosphère à telle hauteur qu'on le désire, et comme cet air peut alors être admis dans des caves complétement closes, où personne n'a besoin de pénétrer, il s'ensuit qu'il serait à la fois plus pur et moins échauffé que dans le système où l'on a recours à des appareils mécaniques.

L'exemple des mines de houille, déjà cité, où l'air descend, par l'action de l'appel, à des profondeurs de 300 à 400 mètres, celui de l'hôpital de Guy, à Londres, où l'air est puisé dans l'atmosphère à 29$^{m}$.00 au-dessus du sol, prouvent que le système de l'aspiration peut aussi jouir de la même facilité.

Nous devons ajouter que, si les prises d'air au-dessus du sol

certaine hauteur par les partisans de l'insufflation, ils en ont fait une autre plus grave au point de vue purement mécanique. Il est, en effet, bien reconnu que le passage seul de l'air, à travers un ventilateur en marche, suffit pour augmenter notablement sa température.

Le fait a été constaté, sans explication et abstraction de toute considération scientifique, par MM. E. Trélat et H. Péligot, qui ont observé, le 14 août 1856, les températures suivantes, à l'hôpital Lariboisière :

| | |
|---|---|
| Près du sol et à l'ombre. . . . . . . . . . . . . . . | 14° |
| A la base du clocher. . . . . . . . . . . . . . . . . . | 14° |
| A la sortie du ventilateur. . . . . . . . . . . . . . . | 19° |

Dans des expériences récentes faites sur un ventilateur qui produisait dans l'air une augmentation de pression, mesurée par une colonne de 0$^{m}$.05 d'eau, l'élévation de température de l'air a été de 14°.

L'échauffement de l'air, à son passage par le ventilateur, tient, dans l'hôpital Lariboisière, à deux causes : La première est la présence de la machine à vapeur motrice dans la même pièce que le ventilateur; on pourrait l'éviter dans d'autres installations en isolant ces deux appareils; la seconde, qui se produirait partout, est la compression déterminée par le ventilateur lui-même sur l'air qu'il refoule et la transformation en chaleur du travail moteur nécessaire à cet effet. Ces effets sont inévitables et d'autant plus sensibles que le ventilateur marche plus vite et augmente davantage la pression de l'air. Cela constitue pour la saison d'été un inconvénient grave du système de la ventilation par insufflation. Les partisans de ce système sont complétement en désaccord en cela avec le principe de la transformation du travail en chaleur. A. M.

n'ont pas tous les avantages qu'on leur a attribués, elles n'en sont pas moins très-convenables dans beaucoup de cas, parce qu'elles sont à l'abri des émanations qui peuvent se produire à la surface du sol ou dans les parties inférieures des bâtiments, par accident, par négligence ou par malveillance.

### DU VOLUME D'AIR NOUVEAU FOURNI DANS LES SALLES.

L'action d'un ventilateur énergique bien établi, comme ceux qui existent à l'hôpital Lariboisière, est certainement un moyen de faire arriver dans un lieu déterminé un volume d'air parfois considérable. Dans les galeries de mines, dans le percement des tunnels, où il n'est pas toujours possible d'établir une circulation naturelle de l'air, ces appareils peuvent être d'un grand secours.

Mais il faut éviter de se faire illusion sur l'effet des appareils de ce genre et des autres machines soufflantes, et surtout il ne faut pas admettre, comme l'ont fait, dans ces derniers temps, quelques ingénieurs qui se sont occupés de la question de ventilation, que le volume d'air refoulé à l'origine des conduits arrive nécessairement en entier dans les salles. L'existence inévitable de joints nombreux, et surtout la porosité des maçonneries permettent à l'air, légèrement comprimé dans les conduits, de s'échapper à l'extérieur dans une proportion d'autant plus considérable que les conduits sont plus longs, et il arrive même parfois qu'il n'en parvient presque point à leur extrémité. L'exemple ancien d'une forge établie, à la fin du siècle dernier, par le célèbre Wilkinson, et cité par votre rapporteur, en est une preuve. L'impossibilité de maintenir la pression produite par des machines soufflantes puissantes dans des régulateurs en maçonnerie faits avec le plus grand soin et même dans des récipients en métal, les expériences récentes par lesquelles M. H. Deville a montré que les tubes en biscuit de porcelaine, que les métaux mêmes sont perméables aux gaz, tous ces exemples, enfin, prouvent que, dans les conduits destinés à laisser circuler de l'air sous une certaine pression, il se fait nécessairement des pertes plus ou moins considérables.

Les ingénieurs qui ont admis que tout le volume fourni par les ventilateurs de l'hôpital Lariboisière arrivait nécessairement

dans les salles, et qui ont été ainsi conduits à estimer à 90, à 100 mètres cubes et même plus haut le volume d'air nouveau introduit dans ces salles par heure et par lit, sont donc tombés dans une erreur grave.

Les observations directes faites au débouché des poêles leur montraient cependant qu'entre le volume fourni par le ventilateur et celui qui arrivait réellement par ces poêles il y avait une différence, un déchet notable, qui réduisait, pendant l'hiver et au printemps, le volume d'air nouveau réellement admis à 60 ou 70 mètres au plus par heure et par lit, quand la machine marchait à 70 ou 80 tours par minute.

Mais il ne faut pas oublier que, pendant la saison du chauffage, l'élévation de la température d'une partie des conduits et surtout celle des poêles que traverse l'air avant de pénétrer dans les salles, contribue, dans les pavillons 2, 4, 6, ventilés par insufflation, comme dans les pavillons 1, 3, 5, ventilés par appel, à déterminer l'introduction de l'air, et concourt, avec le ventilateur, à l'effet obtenu.

Des expériences spéciales faites par votre rapporteur, et d'autres dues à M. l'ingénieur de l'Assistance publique pour reconnaître quelle était en réalité, dans les effets produits, la part du ventilateur et celle de l'aspiration déterminée par la chaleur des poêles, ont conduit aux résultats consignés dans le tableau suivant, que nous reproduisons ici, parce qu'ils se rapportent à l'un des points les plus controversés de la question.

*Résultats des Expériences comparatives faites pour déterminer la part proportionnelle du ventilateur et celle de l'aspiration dans l'admission de l'air nouveau par les poêles des pavillons 2-4-6 de l'hôpital Lariboisière.*

| DATES. | TEMPÉRATURES | | | EXCÈS de la température de l'air affluent sur celle de l'air extérieur. | MODE d'observation. | CONDITIONS de l'expérience. | VOLUME d'air introduit par heure. | PART PROPORTIONNELLE | | LIEU des observations. |
|---|---|---|---|---|---|---|---|---|---|---|
| | extérieure. | des salles. | de l'air affluent. | | | | | du ventilateur. | de l'aspiration. | |
| | | | | | *Expériences du général Morin.* | | mèt. c. | | | |
| 10 janvier 1861. | » | » | » | » | Avec un tuyau placé sur le poêle. | Machine en marche, 74 tours. | 695 | 0,414 | 0,59 | Pavillon n° 4. Poêle n° 1. Premier étage. |
| | | | | | | — Machine arrêtée. | 407 | | | |
| 11 janvier 1861. | — 5° | 19° | 43° | 18° | *Id.* | Machine en marche, 70 tours. | 568 | 0,31 | 0,66 | |
| | | | | | | — Machine arrêtée. | 378 | | | |
| 5 janvier 1864. | — 5,5 | 18,5 | 41<br>49 | 46,5<br>54,5 | Dans les conduits du poêle. | Machine en marche, 89 tours. | 641 | 0,42 | 0,58 | |
| | | | | | | — Machine arrêtée. | 369 | | | |
| 5 janvier 1864. | — 5,5 | 18,5 | 41<br>49 | 46,5<br>54,5 | Avec un tuyau placé sur le poêle. | Machine en marche, 89 tours. | 720 | 0,48 | 0,52 | |
| | | | | | | — Machine arrêtée. | 371 | | | |
| | | | | | *Expérience de M. l'ingénieur de l'Assistance publique.* | | | | | |
| 15 décembre 1864. | + 5°.0 | 18°,0 | » | » | Avec un tuyau placé sur les poêles. | Machine en marche, 85 tours. | 5047 | 0,54 | 0,46 | Tous les poêles du pavillon. |
| | | | | | | — Machine arrêtée. | 2336 | | | |

On fera remarquer que, dans les expériences exécutées le 15 décembre 1863 et le 5 janvier 1864, la machine marchait à des vitesses comprises entre 85 et 89 tours en 1′, tandis que, dans celles de janvier 1861, la vitesse n'était que de 70 à 74 tours.

D'une autre part, le 15 décembre 1863, lorsque M. l'ingénieur de l'Assistance publique a opéré, la température extérieure était supérieure à 5° et la vapeur ne circulait dans aucun des poêles des salles, ce qui tendait évidemment à diminuer notablement les effets de l'aspiration.

Malgré ces deux circonstances réunies, qui, dans l'expérience de M. l'ingénieur de l'Assistance publique, concouraient à diminuer l'influence de l'aspiration, sa part proportionnelle, dans le volume d'air total introduit, ne s'en est pas moins élevée à 0,46.

Ce qui prouve d'ailleurs que, dans la saison froide, l'aspiration a une influence notable sur l'introduction de l'air par les poêles de ce système de ventilation, c'est qu'au mois de mars et d'avril, par une température extérieure de 14°, et, par conséquent, par un chauffage très-modéré ou peut-être nul, lorsque la machine marchait à 63 ou 70 tours en 1′, le volume d'air fourni par les poêles n'était plus que de $50^{mc},59$ à $41^{mc},75$ par heure et par lit (expériences inédites de MM. Leblanc et Ser, 28 mars et 16 avril 1861), et que, le 20 avril, il s'est abaissé à $40^{mc},000$, parce que, dans ces circonstances, l'effet de l'aspiration était considérablement diminué par la cessation du chauffage des poêles[1].

1. *Remarque sur le mode d'observation à suivre pour déterminer le volume d'air fourni par des orifices ou des bouches de poêle.* — Quelques observateurs, peu familiarisés avec les circonstances du mouvement des fluides pour déterminer les volumes d'air introduits dans des locaux ventilés, se sont contentés de présenter, au-dessus des grilles que cet air traverse, un anémomètre, dont les indications, plus ou moins variables selon la position où il était placé, leur servait à déterminer une vitesse qu'ils prenaient pour celle de l'écoulement. Cette méthode est complétement erronée et ne peut conduire qu'à des appréciations fausses. Pour obtenir aussi exactement que possible la vitesse et le volume de l'air introduit, il convient de placer au-dessus ou au-devant des orifices d'arrivée un tuyau à contours continus, terminé par une partie cylindrique de $0^{m},60$ à $0^{m},70$ de longueur, présentant une section de passage au moins égale en superficie à

Tous ces faits justifient donc cette conclusion parfaitement conforme aux principes de la science, que plus la température est basse et exige un chauffage actif des poêles, plus l'aspiration produite par la différence des températures contribue à l'introduction de l'air par les poêles des salles; et qu'à l'inverse, dans la belle saison, pour obtenir l'introduction d'un même volume d'air, il faut accélérer d'autant plus la vitesse du ventilateur qu'il fait plus chaud à l'extérieur, ce qui conduit à une dépense plus considérable, à laquelle le résultat obtenu n'est d'ailleurs pas proportionnel [1].

### CONCLUSIONS RELATIVES A L'INTRODUCTION DE L'AIR NOUVEAU DANS LES SALLES.

Si l'on remarque que, dans les pavillons dont il est actuellement question, l'action cependant si manifeste de l'aspiration ne se produit qu'en faisant circuler l'air dans de longs conduits, qui seraient en très-grande partie supprimés si la ventilation se faisait simplement par appel, l'on en conclura avec votre Commission que : *l'introduction de l'air neuf en quantité déterminée et la prise de cet air à telle hauteur qu'on le juge convenable, peuvent, au moyen de bonnes dispositions, être aussi bien assurées par les appareils qui procèdent par aspiration que par les moyens mécaniques.*

### OBSERVATIONS RELATIVES AUX APPAREILS DU DOCTEUR VAN HECKE.

Cette conclusion, déduite d'observations et d'expériences nombreuses faites sur les appareils d'insufflation les mieux com-

l'air libre de la grille. On place l'anémomètre dans le tuyau cylindrique à $0^m,10$ ou $0^m,15$ de son extrémité, et l'on y observe la vitesse moyenne de l'air à l'aide de cet instrument. A. M.

1. Nous ne possédons aucune expérience sur les volumes d'air fourni pendant l'été par les poêles des appareils ventilateurs par insufflation. La raison en est que dans cette saison l'on ouvre les fenêtres pendant le jour, ce qui suffit largement. Mais il ne devrait pas en être de même pendant la nuit, et cependant c'est ce qui arrive trop souvent par nécessité et malgré les ordres contraires. Je m'en suis assuré personnellement. Les grandes portes des salles communiquant avec les escaliers sont d'ailleurs ouvertes d'une manière permanente dans cette saison, et comme l'aspiration agit fort peu sur l'évacuation, la marche de la ventilation est alors complétement troublée. A. M.

binés qui aient été construits, est *a fortiori* plus exacte en ce qui concerne ceux que le docteur Van Hecke a établis à l'hôpital Necker et à l'Asile impérial du Vésinet.

Si les expériences dont nous avons rapporté plus haut les résultats généraux ont montré que, dans ce dernier établissement, l'action du ventilateur sur l'évacuation de l'air vicié est sensiblement nulle, il en est encore à peu près de même pour l'introduction de l'air neuf.

En effet, des expériences spéciales, exécutées le 19 janvier 1861 [1], ont fait voir que le volume d'air total introduit dans la

[1]. *Études sur la ventilation*, par A. Morin, 1er vol., p. 513.

*Expériences faites le 19 janvier 1861, à l'Asile impérial du Vésinet, sur les volumes d'air introduits dans les chambres du calorifère.*

| DÉSIGNATION des ORIFICES. | TEMPÉRATURES de l'air à l'entrée. | DIMENSIONS des ORIFICES. | DEUXIÈME SÉRIE. APPEL SEUL. Observateur. | Tours de l'anémomètre en 1'. | Vitesse en 1''. | Volume d'air introduit en 1''. | TROISIÈME SÉRIE. VENTILATEUR ET APPEL. Observateur. | Tours de l'anémomètre en 1'. | Vitesse en 1''. | Volume d'air introduit en 1''. |
|---|---|---|---|---|---|---|---|---|---|---|
| | o | m.q. | | | m. | m.c. | | | m. | m.c. |
| Orifices latéral. . . . | 9o,0 | 0,485×0,64=0,314 | V | 910 | 1,66 | 0,5153 | V | 595 | 1.21 | 0,3755 |
| Orifices latéral. . . . | 9o,0 | 0,50 ×0,60=0,300 | V | 900 | 1,65 | 0 4950 | V | 618 | 1,24 | 0,3720 |
| Orifices du ventilateur. | 9o,0 | 0,50 ×0,60=0,300 | L | 226 | 0,47 | 0,1441 | L | 718 | 1,19 | 0,3570 |
| Orifices du ventilateur. | 9o,0 | 0,50 ×0,60=0,300 | L | 250 | 0,50 | 0,1500 | L | 924 | 1,50 | 0,4550 |
| Volumes totaux. . . . . . . . . . . . . . | | | | | | 1,3044 | | | | 1,5545 |

*Examen des résultats consignés dans ce tableau.* — La valeur des volumes totaux d'air introduits dans la chambre à air montre d'abord que, pour l'introduction de l'air dans la chambre du calorifère, le ventilateur n'a guère plus d'influence que pour l'ensemble de la ventilation, puisque l'aspiration seule, même dans les conditions très-défavorables dans lesquelles elle agissait en partie, a produit un volume d'air de $1^{mc},3044$ qui est les 0,84 du volume introduit par l'action simultanée du ventilateur et de l'appel, et le résultat aurait encore été plus favorable à l'action de l'appel, si les orifices latéraux avaient été suffisamment grands pour dispenser d'en laisser arriver par les conduits du ventilateur.

C'est ce qui est rendu évident dans la deuxième série d'expériences faites avec l'appel seul par la différence des volumes introduits par les orifices latéraux qui ont été de $0^{mc},5153$ et $0^{mc},4950$ ; tandis que ceux qui sont passés par les orifices venant du ventilateur n'ont été que de $0^{mc},1441$ et $0^{mc},1500$.

*Rapport du volume d'air introduit dans la chambre à air au volume total évacué*

chambre à air du calorifère du pavillon F était, en une seconde :

Par l'action seule de l'appel, égal à. . . . . . . . . . $1^{mc},304$

Par l'action combinée de l'appel et du ventilateur. $1^{mc},554$; ainsi l'action seule de l'appel, malgré les conditions défavorables dans lesquelles elle agissait, suffisait pour produire les 0,84 du volume total dû à l'action simultanée des deux causes.

Des résultats analogues ont été constatés par MM. Leblanc et Ser[1], en avril et en mai, à l'hôpital Necker, par une température de 8 à 12°, qui dispensait de chauffer les calorifères. Le volume d'air nouveau introduit et celui de l'air vicié évacué ne se sont élevés qu'à 36 ou 40 mètres cubes par heure et par lit, et le ventilateur n'y contribuait que pour $4^{mc},40$ ou pour 1/9 environ.

La disposition des orifices d'arrivée de l'air chaud est, en outre, très-défectueuse dans ce pavillon. Ils sont placés à fleur du sol, et, l'hiver, les courants d'air chaud qu'ils amènent à une température trop élevée sont très-gênants pour les malades voisins.

### DÉPENSES FAITES PAR LES DIVERS SYSTÈMES DE VENTILATION.

Au point de vue de la dépense d'établissement et de la dépense journalière pour le service et pour l'entretien, la compa-

*par les cheminées.*— Le volume total introduit par l'appel seul a été de $1^{mc},3044$ en 1″, tandis que, dans les mêmes conditions de température intérieure et extérieure, le volume d'air évacué par les cheminées avait été trouvé égal à $2^{mc},3909$ ; le rapport de ces deux volumes égal à

$$\frac{1.3044}{2.3909} = 0.546$$

montre que, dans le pavillon où les expériences ont été faites, malgré l'attention que l'on a toujours eue de veiller à la fermeture des portes et des fenêtres, l'air introduit par la circulation naturelle s'est élevé à

$$2^{mc},3909 - 1^{mc},3044 = 1^{mc},0855$$

par seconde, ou à

$$\frac{1.0855}{2.3909} = 0.455$$

du volume d'air total évacué par les cheminées. Ce résultat, qui montre sous un autre point de vue toute l'influence de la ventilation produite par les différences de température, est d'ailleurs d'accord avec ce que nous avons observé à l'hôpital Lariboisière sur les pavillons ventilés par appel. A. M.

1. *Études sur la ventilation*, t. I^er^, p. 492 et suiv.

raison entre les frais occasionnés à l'hôpital Lariboisière par les deux systèmes mis en présence, est encore à l'avantage de celui qui procède par aspiration.

Les dépenses de premier établissement se sont élevées dans cet hôpital aux chiffres suivants :

Ventilation par insufflation, par lit . . . . . . . . 808 fr. 00
Ventilation par aspiration, par lit. . . . . . . . . 480 fr. 00

L'examen des données recueillies par divers observateurs et de celles que l'administration a fait connaître, en ce qui concerne les dépenses journalières comparées au volume d'air vicié réellement évacué, conduit aux appréciations moyennes suivantes :

| APPAREILS EMPLOYÉS. | PRIX DE LA VENTILATION ANNUELLE à raison d'un mètre cube par heure, intérêts et amortissement du capital | |
|---|---|---|
| | compris. | non compris. |
| Chauffage par la vapeur et l'eau chaude, ventilation par insufflation. | 2 fr. 43 | 1 fr. 30 |
| Chauffage par circulation d'eau chaude, ventilation par appel. | 1 fr. 43 | 0 fr. 79 |

Les chiffres précédents paraîtront sans doute excessifs et seraient certainement susceptibles de faire hésiter plus d'une administration municipale, si l'on n'ajoutait que, par suite de la très-fâcheuse habitude que l'on a trop souvent de n'arrêter les projets des appareils de chauffage et de ventilation que quand les bâtiments sont à peu près terminés, au moins quant au gros œuvre, les dépenses ont été accrues pour cet hôpital dans une proportion énorme.

Des données comparatives relatives à des constructions récentes nous permettent de regarder comme à peu près certain qu'en préparant tous les emplacements et les conduits destinés aux appareils et en employant des dispositifs plus simples, la dépense d'établissement pour un hôpital analogue à celui de Lariboisière ne s'élèverait pas à la moitié du chiffre de 480 fr. par lit, relatif aux appareils de ventilation par appel.

Ainsi, sous le double rapport de la dépense d'établissement et de celle du service journalier, les frais occasionnés par le système de l'insufflation sont à peu près doubles de ceux qu'occasionne celui de l'aspiration.

L'on a prétendu, il est vrai, que les appareils de ventilation avaient été construits en prévision du service complet des six pavillons, ce qui expliquait l'excès de la dépense d'installation; mais cela n'est pas exact, attendu : 1° que l'exécution n'a été autorisée et commencée que pour les trois pavillons 2-4-6, et non pour les six pavillons; 2° que la plus grande partie provient des dépenses de canalisation des conduits d'air et des appareils de chauffage qui n'ont été installés que pour trois pavillons; 3° que les machines établies ne seraient pas suffisantes pour assurer le service de six pavillons.

Quant aux appareils du docteur Van Hecke, l'économie apparente de leur établissement, à laquelle on a attaché trop d'importance, ne provient que de ce qu'ils sont incomplets et d'une construction peu durable. Les tuyaux en tôle des calorifères ne résistent que cinq ou six ans, et exigent de grandes réparations. Le chauffage est tout à fait défectueux.

En comparant d'ailleurs les dépenses annuelles au volume d'air réellement évacué dans des circonstances favorables, on obtient les résultats suivants :

| APPAREIL EMPLOYÉ. | PRIX DE LA VENTILATION ANNUELLE à raison d'un mètre cube par heure, intérêts et amortissement du capital à 10 % | |
|---|---|---|
| | compris. | non compris. |
| Chauffage à l'air chaud, ventilation par insufflation. | 1 fr. 53 | 0 fr. 92 |

## OBSERVATIONS SUR LES DISPOSITIONS DE DÉTAIL.

Les dispositions adoptées dans les divers hôpitaux pour la ventilation par aspiration sont loin d'être irréprochables; bien des proportions devraient être modifiées pour obtenir des résultats complétement satisfaisants. D'une autre part, le système de ventilation par insufflation de l'hôpital Lariboisière ne pourra,

comme on l'a vu, produire une évacuation régulière de l'air vicié que par l'addition d'appareils de chauffage de la cheminée générale d'évacuation; ce qui, en réalité, la ramènerait alors à celui de l'aspiration et conduirait à une augmentation de dépense dans ce système, qui est déjà le plus coûteux.

## CONCLUSIONS GÉNÉRALES.

1° La ventilation a pour objet l'évacuation de l'air vicié et son remplacement par de l'air neuf.

2° Le but principal de la ventilation est l'extraction immédiate de l'air vicié. Elle doit avoir lieu le plus près possible des points où l'air est souillé par des émanations nuisibles, afin d'en prévenir la diffusion dans l'atmosphère des salles. A l'inverse, l'air neuf doit être introduit dans les salles en des points éloignés des malades.

3° Les divers dispositifs qui procèdent par aspiration, lorsqu'ils sont convenablement proportionnés et bien établis, satisfont mieux et plus sûrement aux conditions précédentes que ceux qui procèdent exclusivement par l'insufflation de l'air neuf; ces derniers n'assurent pas en toute circonstance et en toute saison, à l'évacuation de l'air vicié, l'uniformité et la stabilité nécessaires.

4° L'introduction de l'air neuf, pris à telle hauteur que l'on voudra et en quantité suffisante, peut être obtenue par le seul effet de l'aspiration et sans le concours d'appareils soufflants, en donnant aux canaux d'amenée de l'air neuf et à leurs orifices des dimensions assez grandes et des dispositions convenables.

5° L'aspiration peut facilement être déterminée : 1° par les foyers ou calorifères avec cheminées servant au chauffage des salles ou autres appareils analogues, quand il s'agit de salles ou d'hôpitaux de petite ou de moyenne importance; 2° par ces mêmes moyens et au besoin par des foyers spéciaux établis à la base de cheminées de 15 à 20 mètres de hauteur, fonctionnant comme auxiliaires, quand il s'agit d'établissements hospitaliers considérables. L'air à évacuer doit affluer vers la base de la cheminée; le plus souvent il doit y être amené par un ou plusieurs conduits qui, en se ramifiant, vont aboutir à des orifices voisins des sources d'infection.

6° La ventilation par aspiration au moyen de foyers et de cheminées se prête à toutes les dispositions et proportions exigées par la grandeur et la disposition des salles. Elle se rapproche, autant qu'on peut le désirer, de l'aération ordinaire et naturelle des chambres et appartements; elle permet de faire varier le volume et la température de l'air affluent selon les besoins des divers genres de maladies. Elle n'exige que l'établissement peu dispendieux de foyers avec leurs cheminées et de conduits ou canaux qui, une fois établis, coûtent peu d'entretien. Elle ne demande d'autres soins que l'alimentation régulière des foyers, dont tout manœuvre peut être chargé.

La ventilation par insufflation exige, outre les conduits et cheminées d'évacuation communs aux deux systèmes, des machines soufflantes et des machines motrices, avec de longs conduits particuliers pour l'amenée de l'air insufflé. Elle nécessite l'intervention d'ouvriers spéciaux, mécaniciens et chauffeurs, et des frais d'entretien.

7° Le système de l'insufflation n'offre pas les mêmes garanties que le système de l'aspiration contre la diffusion de l'air vicié d'une salle dans une autre, ni contre les rentrées de l'air vicié par les orifices des canaux d'évacuation ou par les fissures de leurs parois, quand une circonstance accidentelle, comme l'ouverture de portes ou de fenêtres, vient troubler l'état habituel de pression et de mouvement de l'air intérieur des salles.

8° L'aspiration déterminée par de simples foyers et cheminées, avec des ouvertures de dimensions suffisantes et convenablement placées pour l'admission de l'air neuf en remplacement de l'air vicié et sans le concours d'aucun appareil mécanique, constitue donc, sauf des circonstances tout à fait exceptionnelles, le moyen le plus facilement applicable d'obtenir une ventilation hygiénique aussi active qu'on puisse le désirer, dans les salles des grands hôpitaux ou dans les hôpitaux de moyenne et de petite importance, susceptibles d'être chauffés par un foyer.

9° En ce qui concerne les établissements où l'on serait conduit, par des circonstances spéciales, à recourir aux moyens mécaniques d'insufflation, il conviendrait d'y ajouter l'action d'une aspiration énergique, s'exerçant spécialement sur les points qui donnent lieu à des émanations suspectes.

Le rapport qui précède a été lu en séance du Comité, le 2 juin

1864, et discuté dans les séances des 10, 24 novembre, 8, 21 décembre 1864 et 12 janvier 1865.

Le Comité, après avoir approuvé le rapport, en a voté successivement les conclusions et l'a adopté dans son ensemble, le 26 janvier 1865.

*Le Sénateur Vice-Président,*
DUMAS.

*Le Secrétaire,*
Dr A. DEVERGIE.

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# INSTRUCTIONS
## SUR LES DISPOSITIONS GÉNÉRALES ET SUR LES PROPORTIONS A ADOPTER POUR
# LES APPAREILS DE VENTILATION
## DES HOPITAUX,

Par M. le général **MORIN.**

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On ne se propose, dans l'instruction suivante, que de faire connaître les proportions des parties principales des passages et des conduits qu'il est nécessaire de ménager dans les salles de l'hôpital que l'on veut ventiler pour assurer facilement l'évacuation de l'air vicié et l'introduction de l'air nouveau.

Ces proportions s'appliquent d'ailleurs aux diverses dispositions que les conditions locales peuvent conduire les architectes à adopter.

Le volume d'air à extraire et à introduire dans les salles de malades pouvant, selon les circonstances, varier de 60 à plus de 100 mètres cubes par heure et par lit, on prendra pour base du calcul des proportions des appareils à établir celui de 80 mètres cubes par heure et par lit.

Lorsque les conditions locales le permettront, l'évacuation par appel de l'air vicié aura lieu de préférence, en général, par des conduits descendants, ouverts derrière la tête des lits, à fleur du

plancher, et au nombre d'un au moins pour deux lits dans les hôpitaux ordinaires, et d'un par lit dans les hôpitaux d'accouchement.

Lorsqu'on emploiera pour mode de chauffage la circulation de l'eau chaude, et que les dispositions adoptées ainsi que le voisinage des cheminées d'appel le permettront, on cherchera à utiliser pour l'appel une partie de la chaleur des petits réservoirs d'eau chaude nécessaires aux besoins courants.

Mais, il ne faudrait pas que l'utilité de ces petits réservoirs, qui n'ont qu'une très-faible capacité, conduisît à adopter exclusivement, comme l'a fait M. Léon Duvoir, l'appel par en haut, qui est moins avantageux.

On remarquera que la disposition qui résultera de l'appel par en bas atténuera beaucoup l'affaiblissement occasionné dans les murs par le passage des conduits d'évacuation.

Ainsi, pour un bâtiment ayant trois étages de salles comme ceux de l'hôpital de Lariboisière, les trumeaux du second étage ne recevraient aucun conduit d'évacuation, puisque le leur propre partirait du plancher; ceux du premier étage ne seraient traversés que par un seul conduit venant du deuxième étage; et ceux du rez-de-chaussée ne seraient évidés que par les deux qui correspondraient au premier et au second étage[1].

Les épaisseurs des murs étant plus grandes aux étages inférieurs, ces évidements seront toujours, à proportion, moins fâcheux dans le système de l'appel par en bas que dans celui de l'appel par en haut, qui conduit au contraire à établir le plus grand nombre de conduits dans les trumeaux des étages supérieurs, où les murs ont le moins d'épaisseur.

Cette considération est un motif de plus qu'apprécieront les architectes pour préférer l'appel par en bas à celui qui se ferait par en haut.

1. Les fig. 1 et 2, pl. 27, qui ne représentent que des indications d'ensemble, font voir avec évidence l'avantage que présente l'appel par en bas sur l'appel par en haut, au point de vue de l'affaiblissement que produit dans les murs le passage des conduits d'évacuation de l'air. L'appel par en bas donne d'ailleurs, comme on le sait, la facilité d'utiliser toute la hauteur de la cheminée générale d'évacuation, au bas de laquelle se rendent les conduits pour donner à l'appel toute l'activité désirable. Il constitue un moyen plus économique d'utiliser la chaleur dépensée pour le produire. A. M.

Pour un bâtiment d'une construction analogue à celle de l'hôpital Lariboisière, dont les trumeaux ont au rez-de-chaussée $3^m,05$ de largeur moyenne sur $0^m,80$ d'épaisseur ou $2^{mq},44$ de section, si les deux conduits venaient du premier et du deuxième étage en descendant vers les caves, ils exigeraient au plus dans les murs (en y comprenant les languettes de séparation et même le parement intérieur en briques de champ) une tranchée de $2 \times 0^m,30 + 0^m,05 = 0^m,65$ de large sur $0^m,22 + 0^m,05 = 0^m,27$ de profondeur, ou en tout $0^{mq},1755$ de section, c'est-à-dire $\frac{1}{14}$ de la section totale du trumeau seul, ce qui ne peut avoir aucune influence sur la stabilité d'un édifice bien construit et bien ancré.

A l'inverse, si l'évacuation se faisait par en haut, les trumeaux du deuxième étage qui n'auraient que $3^m,05 \times 0^m,60 = 1^{mq},83$ de section devraient être traversés par trois conduits exigeant une tranchée de $3 \times 0^m,30 + 0^m,10 = 1^m,00$ de large sur $0^m,27$ de profondeur ou $0^{mq},27$ de section, ce qui équivaudrait à 1/7 de celle de la maçonnerie : cela ne serait pas encore inadmissible.

Dans le cas où les conduits d'introduction d'air nouveau devraient être aussi pratiqués dans les trumeaux, ce que l'on pourra éviter quelquefois dans les hôpitaux dont les salles n'auront qu'un nombre de douze à quatorze lits, on verrait encore que l'affaiblissement des murs par le passage de tous les conduits ne compromettrait pas la solidité des murs, convenablement reliés entre eux et ancrés.

Lorsque la nature des matériaux employés ou des conditions locales ne permettraient pas de donner aux murs des épaisseurs suffisantes pour y pratiquer ces passages avec sécurité, on pourra établir les gaînes d'évacuation et d'arrivée de l'air en saillie à l'intérieur des salles.

Alors, pour diminuer le moins possible la largeur disponible de ces salles et ne pas nuire à leur aspect, on restreindra l'épaisseur des gaînes en leur faisant occuper à peu près toute la largeur des trumeaux.

On prendra les dispositions nécessaires pour que les gaînes ou conduits d'évacuation ne soient pas traversés par les poutres ou solives du plancher, ce qu'il sera facile d'éviter à l'aide des chevêtres.

S'il n'y a pas de caves dans les bâtiments, ce qui d'ailleurs n'est pas indispensable, on établira des arceaux assez grands pour donner les sections de passage nécessaires, et ils seront à l'extrados recouverts, comme le reste du sol du rez-de-chaussée, d'une aire en béton avec enduit de bitume pour préserver ce rez-de-chaussée de l'humidité.

Si quelque difficulté s'opposait à ce que les conduits d'évacuation descendissent au-dessous du sol du rez-de-chaussée, on les terminerait à hauteur de ce sol. Ce n'est que dans des cas exceptionnels, ou pour des bâtiments existants qui offriraient des obstacles particuliers, que l'on dirigerait ces conduits de bas en haut vers les étages supérieurs ou vers les combles.

Dans tous les cas, les conduits d'évacuation de l'air vicié correspondant à des lits placés aux différents étages, les uns au-dessous des autres, resteront isolés dans leur parcours vertical, et ils ne seront réunis par groupes dans des conduits collecteurs partiels et horizontaux qu'après y être demeurés séparés par des languettes sur une étendue de trois à quatre mètres au delà du débouché de ceux qui seront les plus voisins de la cheminée générale d'évacuation, afin de s'opposer autant que possible à l'établissement de communications d'un étage à un autre.

On calculera la section à donner aux premiers conduits d'évacuation en comptant sur l'extraction d'un volume d'air de $80^{mc}$. par heure ou de $\frac{80^{mc}}{3600} = 0^{mc},0222$ en une seconde et par lit, et sur une vitesse moyenne de passage de $0^{m},70$ en une seconde, ce qui conduit à leur donner $\frac{0^{mc},022}{0^{m},70} = 0^{mq},0320$ de section par lit; et, comme on peut admettre que, dans les hôpitaux ordinaires, il suffira d'un conduit pour deux lits, il devra avoir $0^{mq},064$ de section, ou par exemple $0^{m},22$ de profondeur sur $0^{m},30$ de largeur.

Pour les hôpitaux de femmes en couches, le volume d'air à évacuer par lit étant de 100 mètres cubes par heure ou de $0^{mc},028$ par seconde, la section des premiers conduits sera de $0^{mq},040$ pour un lit.

Dans les premiers conduits collecteurs, qui réuniront les précédents par groupes, on admettra que la vitesse moyenne sera de $1^{m},00$ à $1^{m},20$ en $1''$, et l'on calculera la section d'après cette

base et d'après le nombre de lits dont ils devront assurer l'assainissement.

Les seconds conduits collecteurs, si l'on en établit pour réunir tout l'air vicié évacué par les précédents, seront proportionnés en y supposant une vitesse moyenne de $1^m,40$.

Enfin, dans la cheminée générale d'évacuation, on admettra que la vitesse moyenne doit être d'environ $1^m,80$, et qu'à sa partie supérieure elle sera au moins de $2^m,00$ en $1''$, afin de la mettre à l'abri des bourrasques.

Par l'adoption du système de l'appel exercé par en bas, une même cheminée générale d'évacuation pourra, dans beaucoup de cas, servir pour plusieurs pavillons, en se réservant les moyens d'interrompre, à l'aide de portes, les communications avec ceux qui ne seraient pas occupés.

Au bas de la cheminée on établira une grille en fer entourée d'un rebord en briques et qui sera complétement isolée des parois, afin que l'air affluent des conduits collecteurs puisse en partie circuler autour et ne s'échauffer qu'à une température modérée ou suffisante[1].

Cette température intérieure moyenne de la cheminée doit en toute saison excéder d'une quantité constante, de 20 à 25 degrés en général, celle de l'air extérieur, pour donner à l'appel et en tous temps la même énergie; le feu du foyer d'appel devra donc être beaucoup plus énergique l'été que l'hiver.

Des dispositions analogues proportionnées d'après les mêmes bases seront prises dans le cas où la répartition adoptée pour les divers pavillons conduirait à n'établir qu'une seule cheminée d'évacuation pour un plus grand nombre de bâtiments.

Lorsqu'au lieu d'être séparées des bâtiments ces cheminées y seront accolées, ou placées à l'intérieur, on profitera autant que possible de la chaleur qu'on pourrait emprunter aux réservoirs d'eau chaude, aux fourneaux à cataplasmes, et en général à tous les appareils nécessaires de service.

Quand la disposition générale adoptée pour les bâtiments

1. Dans tous les cas, l'on devra ménager une entrée directe, ouvrant à l'extérieur à la base de la cheminée, et par laquelle le chauffeur viendra alimenter le four. S'il était obligé de faire son service par les galeries d'évacuation, il courrait risque d'être asphyxié, ou au moins fort incommodé. A. M.

comprendra une galerie de promenade au long d'une des longues faces, l'appel pourrait être exercé à hauteur de chaque étage, et de manière à éviter l'ouverture d'aucun conduit vertical dans les murs pour l'évacuation de l'air vicié, en plaçant la cheminée en un point de cette galerie d'évacuation vers laquelle les conduits partiels seraient dirigés en passant dans des entrevous disposés au plafond des corridors [1].

Une pareille disposition permettrait d'utiliser plus facilement que toute autre, pour activer la ventilation, une partie de la chaleur des petits réservoirs d'eau chaude nécessaire au service et pour les bains, celle des fourneaux à cataplasmes, sans tomber dans les inconvénients que l'on reproche, non sans raison, à la disposition que L. Duvoir avait exclusivement adoptée.

Dans ce cas, chaque pavillon aurait sa cheminée générale d'évacuation recevant à hauteur de chaque étage l'air vicié qui en proviendrait dans des gaînes spéciales isolées les unes des autres jusqu'au-dessus de l'étage supérieur; au bas de chacune de ces gaînes collectives, on pourrait disposer un petit foyer auxiliaire d'appel qui ne servirait que dans les cas où son action serait indispensable pour obtenir un appel assez énergique.

Il doit être d'ailleurs bien entendu que, dans tous les cas, la surface intérieure des gaînes et des conduits collecteurs devra être recouverte d'un enduit aussi bien lissé que possible, pour diminuer la résistance des parois au mouvement de l'air, et que des ouvertures ou regards y seront ménagés pour permettre de les nettoyer au moins deux fois par an, afin d'enlever les toiles d'araignées et autres obstacles susceptibles de gêner la circulation de l'air.

En général, il serait convenable de faire surmonter la cheminée d'évacuation par un appareil à girouette dont le vent dirigerait l'orifice d'évacuation du côté d'aval, ce qui permettrait d'utiliser l'action des courants d'air les plus énergiques au profit de l'appel, qu'ils contrarieraient sans cette précaution.

Les proportions et les dispositions générales que l'on vient d'indiquer seront aussi observées lorsqu'on aura été obligé de

1. Voir plus loin les projets présentés pour ce cas par M. L. Duvoir et par M. d'Hamelincourt. A. M.

faire l'appel de l'air vicié soit au niveau des salles comme on l'a indiqué plus haut, soit par la partie supérieure des bâtiments, ainsi que cela peut arriver, surtout quand il s'agit de bâtiments existants.

Toutes les fois que les conditions locales le permettront, les tuyaux de fumée des appareils de chauffage seront dirigés dans la cheminée générale d'évacuation pour utiliser la chaleur abandonnée par leurs parois, ils y seront isolés, et seront en fonte.

Les foyers des chaudières de la buanderie seront, s'il est possible, établis à la base même de cette cheminée, afin d'utiliser au profit de la ventilation la chaleur acquise dans ces foyers par les gaz produits de la combustion.

*Exemple.* Comme simple application des règles précédentes, nous supposerons qu'il s'agisse d'un hôpital de 100 lits répartis dans deux pavillons auxquels on ne donnerait qu'une même cheminée d'évacuation, et qu'il y ait deux étages contenant ensemble 50 lits par pavillon, distribués dans quatre salles de 12 lits, et deux chambres à un lit. Dans cette hypothèse, chaque salle contiendrait 6 lits sur chaque face, et il y aurait deux conduits d'évacuation de $0^{m},064$ de section, ou de $0^{m},22$ sur $0^{m},30$ intérieurement et deux de $0^{mq},032$ soit $0^{m},16$ sur $0^{m},20$.

Ces conduits verticaux descendront au-dessous du sol du rez-de-chaussée et se réuniront deux à deux au nombre de six dans de premiers collecteurs horizontaux destinés à livrer passage à l'air appelé par les premiers, et qui chacun devront évacuer $12 \times 0^{mc},0222 = 0^{mc},266$ en 1 seconde, à la vitesse de $1^{m},00$ en 1 seconde; ils auront donc une section de $0^{mq},266$ ou $0^{m},52$ sur $0^{m},52$, par exemple.

L'un de ces conduits qui évacuerait en outre l'air des deux chambres à un lit, ou $14 \times 0^{mc},0222 = 0^{mc},31$, devrait avoir $0^{mq},31$ de section ou $0^{m},52$ sur $0^{m},60$.

Si ces conduits n'arrivent pas directement à la base de la cheminée, et si les dispositions générales adoptées obligent à réunir les premiers collecteurs de chaque pavillon dans une deuxième galerie ou 2e collecteur, on aura pour le volume d'air auquel ils devront donner passage $50 \times 0^{mc},0222 = 1^{mc},11$, avec une vitesse de $1^{m},40$. Leur section transversale sera alors égale à $\frac{1^{mc},11}{1^{m},40} = 0^{mq},79$ ou $0^{mq},80$ et pourra avoir $0^{m},90$ sur $0^{m},90$. Si la

cheminée générale doit évacuer l'air vicié des deux pavillons, ou pour 100 lits 8,000$^{mc}$ par heure ou 2$^{mc}$,222 en 1″, à la vitesse moyenne de 1$^{m}$,80 en 1″, sa section sera égale à $\frac{2^{mc},222}{1^{m},80} = 1^{mq},24$ et son diamètre moyen sera 1$^{m}$,255. Celui du sommet sera réduit à 1$^{m}$,19 pour y obtenir la vitesse de 2$^{m}$,00 en 1″.

## INTRODUCTION DE L'AIR NOUVEAU.

Les orifices d'introduction de l'air nouveau, chaud ou frais, seront toujours pratiqués près du plafond, et répartis aussi uniformément que possible dans toute l'étendue des salles, à raison d'un pour deux lits s'il se peut, ou d'un au moins pour quatre lits. Quand ils seront ouverts dans les parois verticales des murs, ils seront munis de cloisons directrices en forme de jalousies inclinées à 20 ou 25 degrés à l'horizon, de bas en haut, afin de faire affluer l'air dans ce sens vers le plafond.

La section transversale des conduits verticaux ou autres sera calculée de manière que l'air les parcoure avec une vitesse qui n'excède pas 1$^{m}$,00 à 1$^{m}$,20. Celle des passages immédiats d'affluence de l'air dans les salles sera déterminée par la condition que la vitesse dirigée vers le plafond n'atteigne aussi que 1$^{m}$,00 à 1$^{m}$,20 en 1 seconde.

Dans le cas où l'air affluerait de haut en bas dans le sens vertical par des ouvertures ménagées dans le plafond même, ce qui peut arriver si l'on emploie des doubles planchers ou quand on aura une capacité servant de chambre à air, la somme des sections libres de passage par les orifices devra être calculée par la condition que la vitesse n'excède pas 0$^{m}$,50 à 0$^{m}$,60 en 1 seconde.

Lorsqu'on se servira pour le chauffage de calorifères ordinaires, l'air chaud qu'ils fourniront devra être introduit, avant son entrée dans les salles, dans une chambre de mélange, où l'on pourra faire arriver de l'air extérieur en proportion convenable pour modérer selon les besoins la température de l'air à fournir aux salles[1].

1. Pour assurer le mélange de l'air extérieur frais avec l'air chaud fourni par l'appareil de chauffage, il convient d'imiter dans tous les cas la disposition que nous avons adoptée pour les amphithéâtres du Conservatoire, c'est-à-dire de

Dans la saison du chauffage, la température de l'air affluent devrait, pour une ventilation salubre, différer très-peu de celle que l'on veut maintenir dans les salles, et qui doit être habituellement de 15 à 16 degrés.

Ces chambres de mélange pourront être formées soit par des entrevous pratiqués au-dessus des calorifères, soit dans des corridors ou des pièces de petites dimensions.

Des registres seront disposés dans les chambres de mélange pour permettre de faire varier à volonté et selon les besoins la température de l'air qu'elles fourniront.

On atténuera beaucoup d'ailleurs les défauts des calorifères à air chaud en disposant au-dessus de leur grille une cloche à double paroi remplie d'eau, qui recevrait l'action directe du feu et servirait en outre à alimenter les réservoirs d'eau chaude. Des dispositions analogues seront prises lorsqu'on emploiera des appareils de chauffage par l'eau chaude ou par la vapeur.

Si l'hôpital est convenablement isolé et situé dans une position salubre, les prises d'air extérieur pourront être faites soit à fleur du sol, au milieu de pelouses de verdure ou de jardins (comme à Vincennes, à l'hôpital d'accouchement de Saint-Pétersbourg), soit à hauteur des divers étages ; et l'on ne devra recourir aux cheminées d'appel descendant pour prendre l'air à une certaine hauteur que dans les cas où la proximité de bâtiments plus ou moins insalubres donnerait lieu de craindre l'infection de l'air à la surface du sol. On aura soin alors de placer la cheminée de prise d'air aussi loin que possible de celle d'évacuation générale. La section de cette cheminée, et en général celle de tous les orifices extérieurs de prise d'air, sera calculée de façon que la vitesse d'introduction n'y excède pas $0^m,60$, afin

diriger au moyen de languettes plus ou moins longues, selon les cas, l'air frais au-dessus du courant d'air chaud. Il arrive alors que, le premier plus dense que le second tendant à s'abaisser, tandis que le second, plus léger, tend à s'élever, le mélange se produit nécessairement.

Cette disposition s'appliquerait aussi bien à des orifices isolés et directs d'accès de l'air chaud ou de l'air frais dans les salles qu'à ceux d'affluence dans les chambres de mélange. On en verra un exemple dans le projet de chauffage et de ventilation rédigé par M. D'Hamelincourt pour un pavillon de soixante lits répartis dans trois salles. A. M.

que l'appel qu'ils exerceront dans leur voisinage ne s'étende qu'à une petite distance.

Pour la saison d'été, où l'action de l'appel sur l'introduction de l'air n'est plus favorisée par l'élévation de la température que le chauffage communique à l'air nouveau, l'on devra ménager dans les murs des bâtiments des orifices auxiliaires, disposés comme les précédents et particulièrement ouverts sur les faces exposées au nord ou au levant, et munis de moyens de fermeture qui permettent de les ouvrir ou de les clore à volonté. L'air ainsi introduit pouvant, pendant la nuit, être assez frais, il importe que sa vitesse d'arrivée soit dirigée de bas en haut vers le plafond, et de $0^m,60$ en $1''$ environ, afin qu'elle s'éteigne rapidement avant qu'il n'arrive aux orifices d'évacuation : cette disposition est préférable à celle des fenêtres anglaises.

La manœuvre de tous les registres sera disposée de manière qu'elle ne soit qu'à la disposition des agents préposés au service.

*Règle générale pour le contrôle du service de la ventilation.* — Lorsqu'un dispositif quelconque de ventilation par appel aura été établi, on constatera, par des expériences spéciales faciles à faire, dans la cheminée générale d'évacuation, ou si l'on veut dans les conduits partiels, si le volume d'air prescrit est réellement évacué, et quel est l'excès correspondant de la température dans cette cheminée sur la température de l'air extérieur. Or si, pour cet excès, qui en général ne différera pas beaucoup, comme on l'a dit plus haut, de 20 à 25 degrés, on a obtenu la ventilation voulue, on prescrira de régler le chauffage de la cheminée de telle sorte qu'en tous temps sa température dépasse de la même quantité celle de l'air extérieur.

On fera connaître plus tard des moyens de contrôle qui faciliteront à cet effet la surveillance de MM. les directeurs d'hôpitaux.

*Cas où le chauffage sera fait par des cheminées.* — Lorsque les salles de l'hôpital seront chauffées par des cheminées pour lesquelles on devra préférer la disposition de celles qui déterminent à la fois l'évacuation de l'air vicié et la rentrée d'une proportion assez considérable d'air nouveau convenablement chauffé, à leurs orifices d'introduction l'on en ajoutera d'autres

assez nombreux, et disposés comme on l'a dit pour la ventilation d'été.

Ces cheminées seront d'ailleurs disposées de manière à pouvoir recevoir de petits poêles ou fourneaux à coke ou à houille destinés à produire, l'été, et surtout la nuit, l'appel de l'air nouveau et l'évacuation de l'air vicié.

Les cages d'escaliers, les antichambres et autres pièces donnant accès dans les salles devront être chauffées à une température qui, pour ces dernières surtout, devra être au moins égale à celle des salles. On atténuera ainsi l'effet des rentrées d'air produites par ces ouvertures sous l'action de l'aspiration. Il serait donc convenable d'établir des calorifères généraux pour ces locaux, même quand on se servirait de cheminées à l'intérieur des salles.

*Cuisines et lieux d'aisances.* — Les cuisines et les lieux d'aisances devront être isolés des salles et ventilés par aspiration, d'une manière énergique, par des moyens analogues à ceux que l'on a indiqués.

Le volume d'air qui devra être aspiré sous chaque siége des lieux d'aisances par un conduit spécial ne sera pas moindre de $40^{mc}$ par heure et par siége. Ces conduits d'évacuation de l'air vicié seront calculés par la condition que la vitesse y soit de $0^{m},80$ environ, et l'on aura soin de les mettre en communication directe, s'il est possible, avec la cheminée générale.

*Usage des becs d'éclairage.* — Dans les hôpitaux éclairés au gaz, il sera bon d'utiliser la chaleur développée par les appareils employés à activer cet appel. Tous les cabinets d'aisances seront munis de doubles portes fermant de dehors en dedans dans le sens de l'appel.

*Dispositions pour les cas d'encombrement.* — Lorsque l'appel sera déterminé par la chaleur développée par des appareils de chauffage par circulation d'eau chaude ou de vapeur dont l'énergie ne peut être augmentée beaucoup au delà de certaines limites, comme celle des foyers ordinaires, il sera prudent de disposer dans la cheminée d'appel général des becs de gaz que l'on n'allumera que dans les cas où un encombrement momentané ou la crainte d'influences épidémiques le rendrait nécessaire. On cal-

culera alors le nombre de becs et leur consommation d'après la proportion approximative de 500$^{mc}$ d'air évacué par mètre cube de gaz brûlé.

Ce moyen auxiliaire n'est pas économique, et ne doit être employé que pour des circonstances exceptionnelles, comme celles que l'on a indiquées.

*Observation générale.* — Des proportions analogues à celles dont on a donné l'indication dans cette note pour les appareils fonctionnant par appel seront adoptées dans les établissements où l'on aurait été conduit par des circonstances spéciales à recourir à des moyens mécaniques d'insufflation accompagnés d'appareils d'appel.

On ne croit pas devoir, pour ce cas particulier, entrer dans des détails plus étendus, parce qu'alors les projets devront être étudiés avec le concours d'ingénieurs spéciaux pour ces sortes de travaux.

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# NOTE

## SUR L'APPLICATION DES PRINCIPES ADOPTÉS

PAR LE

COMITÉ CONSULTATIF D'HYGIÈNE ET DE SERVICE MÉDICAL DES HOPITAUX,

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*Application des principes précédents à un pavillon d'hôpital de* 60 *lits.*

Pour montrer, par des études plus détaillées, que les principes adoptés par le comité consultatif d'hygiène et du service des hôpitaux sont facilement applicables et ne conduiraient pas à des dépenses, à beaucoup près, aussi considérables que celles qui ont été faites pour l'hôpital Lariboisière, lesquelles pourraient, avec raison, faire hésiter plus d'une administration à les

adopter, il m'a paru utile de faire rédiger par des constructeurs expérimentés des projets conformes à ces principes, et accompagnés de devis faisant connaître le montant des dépenses inhérentes à l'installation des appareils de chauffage et de ventilation.

Je me suis, à cet effet, adressé à deux des plus habiles constructeurs d'appareils de ce genre, qui aient fait leurs preuves par un grand nombre de travaux, M. Guérin, ingénieur de la maison L. Duvoir-Leblanc, et M. d'Hamelincourt, successeur de René Duvoir. Au lieu de cette rivalité funeste qui avait divisé pendant leur vie les deux frères Duvoir, les ingénieurs qui leur ont succédé ont aujourd'hui le bon esprit de n'avoir entre eux d'autre concurrence que celle de faire le mieux possible. J'ai posé à tous deux les bases du projet à rédiger, et c'est le résultat de leurs études que je fais connaître dans cette note.

Ces études devaient avoir pour objet le chauffage et la ventilation d'un pavillon d'hôpital ayant trois étages de salles de vingt lits chacune, dans l'hypothèse où un corridor de promenade régnerait à chaque étage, dans toute la longueur du bâtiment. L'appel de l'air vicié devait être fait, dans ce cas, à hauteur de chaque étage; ce qui dispensait de pratiquer les gaînes d'évacuation dans l'épaisseur des murs, permettait de les établir dans un entrevous ménagé dans le corridor, et de conduire l'air vicié dans une cheminée unique d'appel, où des foyers d'échauffement devaient être disposés.

Les dispositions proposées par chacun de ces ingénieurs sont indiquées dans les planches 27 et 28, auxquelles je crois utile de joindre quelques explications.

Je dois d'ailleurs faire remarquer que ces projets ne sont étudiés qu'au point de vue du chauffage et de la ventilation, et qu'ils ne comprennent pas ce qui est relatif aux autres services d'un hôpital. Le seul but de ces études était de montrer, par des applications, la marche à suivre et les dispositions générales à adopter pour assurer le chauffage et la ventilation d'un grand pavillon d'hôpital, conformément aux principes admis dans les rapports précédents.

*Projet de M. Guérin, ingénieur de la maison L. Duvoir-Leblanc, pour un pavillon d'hôpital de* 60 *lits.*

Dans ce projet, le chauffage des salles est obtenu par la circulation de l'eau chaude de la manière suivante :

Une chaudière A (pl. 27, *fig.* 3 et 4) échauffe l'eau par un tuyau d'ascension *aaa* et l'envoie dans un récipient supérieur M, (*fig.* 3). De ce récipient partent deux tuyaux PP de distribution, établis parallèlement à l'un des murs de face, et qui sont en communication avec dix séries de trois tuyaux verticaux chacune, placés dans des gaînes ou coffres RRR, que l'auteur a supposés construits en saillie à l'intérieur de la salle. Tous ces tuyaux verticaux sont en communication avec un conduit de retour QQQ qui ramène l'eau à la chaudière A.

Le système fonctionne à basse pression et à l'air libre, avec lequel il communique par un tuyau d'échappement N (*fig.* 3) débouchant au-dessus du toit.

L'air qui doit être introduit et échauffé dans les coffres au contact des tuyaux est pris sur la façade opposée au corridor, à hauteur du plancher de chaque étage, par des orifices KKK (*fig.* 4), ce qui suppose que le pavillon est construit dans un emplacement salubre. Si la situation n'était pas aussi favorable, M. Guérin indique qu'il aurait recours à l'usage d'une cheminée spéciale d'introduction, qui serait établie à l'extrémité du pavillon opposée à celle où est la cheminée d'évacuation, et qu'il ferait alors arriver l'air dans un conduit souterrain, d'où il le distribuerait facilement dans les coffres verticaux.

L'air qui a parcouru les coffres et qui s'y est échauffé débouche à hauteur du plafond sous les corniches par de longs orifices HHH (*fig.* 3), au nombre de six, offrant ensemble $1^{mq},30$ de superficie ; ce qui est largement suffisant pour assurer l'introduction de l'air en été, aussi bien qu'en hiver, avec des vitesses très-faibles.

L'évacuation de l'air vicié est produite par l'appel que détermine, pendant l'hiver, le tuyau de fumée du calorifère. Il est extrait des salles par des orifices EE (*fig.* 3, 4 et 5) ménagés dans les trumeaux entre les lits, à raison d'un pour deux lits. L'air vicié venant du côté opposé au corridor passe dans un conduit

pratiqué dans l'épaisseur du plancher, et vient gagner des conduits collecteurs G G G (*fig.* 3 et 4) établis dans un entrevous ménagé dans le corridor au-dessous du plancher de chaque étage. Tous les collecteurs d'un même étage sont isolés les uns des autres par des languettes (*fig.* 3 et 4), jusqu'auprès de la cheminée, où ils débouchent dans le collecteur général de l'étage.

La cheminée générale d'évacuation D D (*fig.* 3, 4 et 5) reçoit les collecteurs généraux, qui s'y prolongent verticalement et sont séparés par des languettes dont chacune s'élève jusqu'au-dessus du plancher de l'étage supérieur. Cette cheminée est surmontée d'un tuyau à girouette qui permet d'utiliser l'action du vent au profit de la ventilation.

Le tuyau de fumée du calorifère circule dans les parties verticales de chacun de ces collecteurs, de manière à y abandonner la chaleur nécessaire pour donner à l'appel l'énergie voulue. Pendant les saisons où le chauffage est ralenti ou supprimé, un petit fourneau ordinaire B (*fig.* 3 et 5) sert de moyen auxiliaire ou unique de déterminer cet appel. Son tuyau de fumée s'embranche dans celui de la chaudière principale.

Ce mode de chauffage de la cheminée d'appel est d'une installation plus économique qu'une circulation spéciale d'eau chaude qui serait établie dans cette cheminée. Il peut être très-énergique, ainsi que l'expérience l'a déjà prouvé; mais sans une surveillance active, il n'est pas d'un effet aussi régulier que le chauffage par l'eau chaude; et je doute qu'il soit même plus économique, parce que les tuyaux inférieurs seront souvent beaucoup plus chauds qu'il ne faudrait, tandis qu'à l'inverse les parties supérieures ne le seront pas assez pendant les ralentissements du feu.

M. Guérin n'a donné, sans doute, la préférence à ce moyen de chauffage que dans la vue de diminuer les frais d'établissement; car il connaît aussi bien que qui que ce soit les avantages du chauffage par circulation d'eau, sous le rapport de la régularité du service, et il lui eût été facile d'indiquer les dispositions à prendre pour l'adopter.

Outre le chauffage des salles par l'introduction de l'air chaud, cet ingénieur a supposé qu'un poêle à eau chaude serait établi dans chacune d'elles pour l'agrément des malades.

L'on remarquera que, dans le projet de M. Guérin, les gaînes

RRR (*fig.* 4) de chauffage et d'arrivée de l'air nouveau ne sont supposées établies que d'un seul côté des salles. Cela ne paraît pas devoir présenter d'inconvénient sérieux, surtout dans la saison du chauffage, attendu que l'observation montre que, malgré l'énergie de l'appel, l'air chaud commence, en affluant, par s'étaler le long du plafond jusque vers le mur opposé, et que ce n'est qu'ensuite qu'obéissant à l'appel il redescend et se dirige vers les orifices d'extraction, dont la répartition symétrique sur les deux faces du bâtiment assurerait l'uniformité de l'évacuation de l'air vicié. Pendant la saison d'été, il est très-probable que les choses se passeraient d'une manière analogue.

Le devis que M. Guérin a joint à son projet ne comprend pas les travaux de maçonnerie relatifs à la cheminée d'évacuation C et aux coffres d'introduction d'air RRR; mais les frais à faire pour établir les conduits FFF et GGG destinés à l'évacuation de l'air y sont comptés. La dépense totale dans ces conditions, pour un hôpital de 60 lits, serait, d'après ce devis, de 13,493 fr., ou de 225 fr. par lit.

Les dispositions proposées par M. Guérin pour le cas particulier qui lui avait été proposé s'appliqueraient en grande partie à des pavillons sans corridor à chaque étage, et il est évident qu'il lui serait facile de les plier à d'autres cas, sans que la dépense dépassât notablement le chiffre auquel s'élève son devis.

Cet ingénieur n'a pas cru devoir rendre le service des bains solidaire de celui de la circulation de l'eau chaude. Il pense qu'il est plus sûr et plus économique d'utiliser pour ce service la chaleur perdue des fourneaux d'office qui fonctionnent en toute saison.

### *Projet de M. d'Hamelincourt pour un pavillon d'hôpital de* 60 *lits.*

Dans ce projet, le chauffage, l'introduction et l'évacuation de l'air sont produits par des appareils de circulation d'eau chaude.

Un calorifère à eau A (pl. 28, *fig.* 2 et 3), placé dans les caves ou dans un caveau spécial, établit pour le chauffage la circulation de l'eau dans une série de conduits verticaux *aaa* correspondants en plan (*fig.* 2 et 3), à l'intervalle de deux lits. Ces conduits sont supposés pratiqués dans l'épaisseur des murs;

ils pourraient, au besoin, être en saillie à l'intérieur, ou même à l'extérieur des salles, sous forme de pilastres.

Le plan du rez-de-chaussée (*fig.* 3) indique la section des tuyaux verticaux d'ascension et de retour et la *fig.* 2, coupe transversale, montre celle des tuyaux généraux d'émission *bb* et de retour *b'b'* renfermés dans deux carneaux horizontaux, qui règnent dans toute la longueur du bâtiment.

L'auteur a supposé que le pavillon était isolé, placé au milieu de cours et de jardins assez salubres pour permettre de prendre l'air sur les façades du bâtiment par de simples ouvertures ménagées dans les murs. Ce cas se présente souvent, et s'il en était autrement, l'on pourrait, comme on le verra plus loin dans un autre projet de M. d'Hamelincourt, prendre l'air à telle hauteur qu'on le voudrait à l'aide d'une cheminée spéciale convenablement disposée.

A hauteur du plafond de chaque étage, les conduits *aaa* sont fermés par un diaphragme et partagés ainsi en trois tronçons que parcourt la série des tuyaux de circulation d'eau, et dont chacun est affecté au service de l'étage correspondant.

Au bas de chacun de ces tronçons, une ouverture *ccc* (*fig.* 2) est ménagée pour l'introduction de l'air extérieur, qui doit s'échauffer au contact des tuyaux d'eau chaude en parcourant le conduit. Cet air, arrêté au sommet des conduits *aaa* (*fig.* 2) par des languettes inclinées, se dirige vers le plafond, dont il suit la surface en perdant sa vitesse d'arrivée.

Au-dessus des languettes directrices de l'air chaud, des ouvertures *c'c'c'* (*fig.* 2) permettent au besoin à l'air extérieur de s'introduire aussi dans les salles vers le plafond.

Cette disposition, qui est une application heureuse faite par M. d'Hamelincourt du principe mis en usage pour la ventilation des deux amphithéâtres du Conservatoire, permet de mêler de l'air frais à l'air chaud fourni par les conduits, pour modérer la température de celui-ci, ainsi que celle des salles. L'orifice d'arrivée de l'air froid plus dense, étant supérieur à celui de l'air chaud plus léger, le mélange des deux courants se fait nécessairement et immédiatement, sans que l'on ait à redouter aucune gêne pour les malades.

Pour la saison d'été, les orifices *ccc* et *c'c'c'* pouvant être ouverts, soit sur l'une des faces ou sur les deux faces du bâtiment,

et les sections des conduits étant calculées d'après les bases indiquées précédemment, l'introduction de l'air pourra être aussi abondamment assurée qu'on le voudra, indépendamment de toute ouverture des portes ou des fenêtres.

Pour l'évacuation de l'air vicié, M. d'Hamelincourt a disposé un orifice et un conduit *ddd* (*fig.* 1, 2 et 3) spécial pour chaque lit. On pourrait probablement, comme on le fait généralement, se contenter d'un conduit pour deux lits, ce qui diminuerait la dépense.

Tous ces conduits passent entre le plancher d'un étage et le plafond de l'étage inférieur, ce qui, par suite de la grande largeur des salles et de la hauteur qu'elle oblige à donner aux poutres en fer, ne conduirait pas à exagérer l'épaisseur totale des planchers.

La figure 3 représentant le plan du rez-de-chaussée montre comment les divers conduits se dirigent horizontalement, en restant isolés, vers la cheminée B d'évacuation. Ils sont séparés par des languettes prolongées jusqu'à cette cheminée.

Celle-ci (*fig.* 1 et 3) est elle-même partagée en trois parties par des languettes verticales suffisamment prolongées pour éviter les communications d'un étage à un autre, de manière qu'elle présente trois gaînes d'évacuation, dont chacune correspond à un étage.

Dans ces gaînes sont disposés des tuyaux de circulation d'eau chaude *eee* (*fig.* 3) communiquant avec un récipient général d'expansion *f* placé à la partie supérieure de la cheminée, et qui sert aussi pour la chaudière principale A.

Cette circulation, destinée à déterminer l'appel, est produite par une chaudière spéciale C (*fig.* 1).

Dans la saison du chauffage, le tuyau de fumée I (*fig.* 3) du calorifère, qui parcourt la cheminée dans toute sa hauteur, contribuerait et suffirait souvent à déterminer l'appel.

L'auteur du projet a supposé qu'à l'extrémité de chaque corridor on établirait une salle de bains, qui serait alimentée l'hiver à l'aide de la circulation générale de l'eau chaude ou par un dispositif spécial.

Les détails dans lesquels nous venons d'entrer suffisent pour faire comprendre les dispositions du projet et le jeu de la venti-

lation, tant pour l'évacuation de l'air vicié que pour l'admission de l'air nouveau, pendant l'hiver et pendant l'été.

L'on remarquera que, dans ce projet, l'appel est produit par un appareil complet de circulation d'eau chaude qui, d'après le devis, coûterait 3,425 fr. Si l'on voulait produire cet appel par de simples poêles, l'on pourrait diminuer la dépense d'environ 2,000 fr.; mais la dépense journalière de combustible compenserait probablement bientôt cette économie.

Au surplus, M. d'Hamelincourt a joint à son projet un devis détaillé des travaux spéciaux de fumisterie à la charge de l'entrepreneur; tous ceux qui seraient relatifs aux maçonneries resteraient à la charge de l'administration. Ce devis s'élève à la somme de 16,835 fr. 50 c.

*Observations sur ce devis.* — L'on voit que la dépense pour l'ensemble des travaux, tels qu'ils sont décrits plus haut, s'élèverait, pour un pavillon de 60 lits, à 16,835 fr. 50 c., ou par lit à 286 fr. Si l'appel était produit non plus par circulation d'eau chaude, mais à l'aide d'un fourneau spécial pour la saison d'été, la dépense d'installation pourrait être réduite d'environ 1,000 à 1,500 fr. Si l'on ne ménageait, comme cela paraît suffisant, qu'une bouche et un conduit d'appel pour deux lits, la dépense serait réduite encore de près de 400 fr., de sorte qu'elle ne s'élèverait en tout, pour les travaux de fumisterie proprement dits, qu'à 14,000 ou 15,000 fr., soit 240 ou 250 fr. par lit.

Cette description montre qu'à part quelques différences dans les dispositions adoptées, et l'influence qu'elles peuvent avoir sur les dépenses, les deux ingénieurs expérimentés auxquels les projets précédents ont été demandés, en s'inspirant des principes adoptés par le Comité d'hygiène et du service des hôpitaux, sont parvenus à proposer des dispositions assez analogues entre elles et à renfermer les dépenses dans des limites beaucoup plus restreintes qu'on ne l'avait fait jusqu'ici pour des installations aussi complètes.

### *Dispositions proposées par M. D'Hamelincourt pour des pavillons sans corridor.*

Outre le projet qu'il a rédigé, à ma demande, pour un pavillon où un corridor servant de promenoir serait établi à chaque

étage, M. D'Hamelincourt a proposé, pour le cas où de semblables corridors n'existeraient pas, les dispositions représentées pl. 28, *fig.* 4, 5 et 6.

Le plan (*fig.* 6) qui est scindé en deux parties représente, par sa moitié de droite M, la disposition correspondante à la coupe suivant A B C D (*fig.*5 ), et par sa moitié de gauche N, celle qui répond à la coupe A′ B′ C′ D′ (*fig.* 4).

Dans le premier dispositif (*fig.* 5 M et *fig.* 6), le chauffage a lieu, comme dans le projet précédent, par circulation d'eau chaude, au moyen de tuyaux qui s'élèvent verticalement dans des gaînes *a a a*, ménagées dans l'épaisseur des trumeaux entre deux lits et particulières à chaque étage. Ces gaînes pourraient être établies en saillie si l'on craignait d'affaiblir les murs. L'introduction de l'air chaud et celle de l'air froid, que l'on voudrait au besoin y mélanger, ont lieu, pour le premier, en bas des conduits par des orifices *c c c* (*fig.* 5), et, pour le second, par des orifices *c′ c′ c′*. Tous deux arrivent vers le plafond sous une inclinaison convenable.

Dans le dispositif (*fig.* 6 N et *fig.* 4), le chauffage a encore lieu à l'aide de l'eau chaude, mais elle ne circule pas dans les conduits et se rend seulement de la chaudière A dans des poêles à eau *g g g* placés dans les caves, et dont chacun est destiné au chauffage de l'air destiné à un même étage.

L'air nouveau devant, dans ce cas, affluer par le bas de chaque conduit, celui qui doit être chauffé ne peut plus être pris par des ouvertures ménagées dans les façades. M. D'Hamelincourt a supposé qu'il serait puisé par l'action de l'appel à une hauteur supérieure à celle du bâtiment au moyen d'une cheminée C (*fig.* 6) placée à l'extrémité opposée à celle où se trouve la cheminée d'évacuation B.

L'air introduit par cette cheminée C gagne deux grands conduits *h h h* (*fig.* 4), parallèles aux longues faces du bâtiment, placés dans les caves, construits avec soin en mortier hydraulique pour les mettre à l'abri de toute infiltration. Ces conduits sont parcourus, dans toute leur longueur, par les tuyaux d'arrivée et de retour *i i i* de l'eau chaude, sur lesquels sont branchées les communications avec les poêles *g g g*.

Ce dispositif de chauffage par circulation de l'eau, dans les parties inférieures du bâtiment, a l'avantage de faire disparaître

les craintes de fuites susceptibles d'altérer les murs, et, sous ce rapport, il pourra convenir à quelques administrations; mais il ne semble pas aussi économique, au point de vue de l'utilisation de la chaleur dépensée, que celui où toute la hauteur des conduits est parcourue par des tuyaux remplis d'eau chaude, avec lequel les fuites sont peu à craindre, quand l'on apporte le soin convenable à son établissement.

On remarquera d'ailleurs que le mode de prise d'air par une cheminée spéciale s'appliquerait aussi bien à l'autre dispositif, ainsi qu'au premier projet, si les conditions locales le faisaient juger nécessaire.

Dans le dispositif représenté pl. 28 (*fig.* 5 M et 6), l'évacuation de l'air vicié se fait par appel par en bas.

Au rez-de-chaussée (*fig.* 5 M et *fig.* 6), l'air vicié est aspiré sous le milieu des lits par des orifices *kkk* et se rend dans des conduits horizontaux *lll*, parallèles aux façades, lesquels débouchent dans un conduit transversal *mm*, qui mène l'air au bas de la cheminée générale d'évacuation B.

Pour le premier et le second étage, l'air est évacué par des orifices placés derrière chaque lit et descend par des conduits *nnn* (*fig.* 5 M et *fig.* 6), ménagés dans les trumeaux ou en saillie vers deux carneaux collecteurs *o* placés dans les caves et qui l'amènent au bas de la cheminée.

Il conviendrait que l'air affluent de chaque lit et de chaque conduit vertical fût, comme dans le premier projet, isolé de celui que les autres fournissent par des languettes disposées dans tous les conduits. Les coupes ne l'indiquent pas, mais cela doit être toujours sous-entendu.

De même, dans la cheminée générale, il serait convenable que l'air vicié affluant par les conduits *ll* du rez-de-chaussée fût séparé, au moins jusqu'à 5 ou 6 mètres de hauteur, de celui qui, par les conduits *oo,* placés plus bas, est venu des étages supérieurs.

Dans le dispositif (*fig.* 4 N et *fig.* 6), le mode adopté pour la circulation de l'eau chaude a permis de ne conserver pour l'évacuation de l'air vicié que les conduits *ooo*, pour la construction desquels on prendra les précautions indiquées ci-dessus.

Les deux dispositions proposées par M. D'Hamelincourt pour des pavillons sans corridor, et dans lesquels la ventilation se

fait par appel en contre-bas, ne conduiraient pas à une dépense plus élevée que celle du premier projet.

Les cheminées d'évacuation seraient, dans tous les cas, surmontées par un tuyau tournant à girouette pour profiter de l'action que le vent peut exercer à l'aide de cet appareil sur l'énergie de l'appel.

### *Application aux petits hôpitaux.*

Outre les dispositions dont je viens de donner la description, j'en ai fait étudier deux autres, basées toujours sur les principes adoptés par le Comité consultatif d'hygiène et du service médical des hôpitaux, et particulièrement relatives aux petits hôpitaux, dans lesquels il n'y aurait que des salles de huit à dix lits. Les conditions d'économie dans lesquelles de semblables hôpitaux doivent être établis m'ont engagé à faire simplifier, autant que possible, l'installation des appareils.

Deux projets ont été étudiés, à ma demande, par M. D'Hamelincourt; mais dans l'un le chauffage est obtenu à l'aide d'un calorifère à eau chaude, sans circulation extérieure, et l'évacuation de l'air vicié des salles de malades, des lieux d'aisances et de la cuisine est produite par appel.

Je crois inutile de décrire les dispositions adoptées, et qui sont d'ailleurs conformes aux principes exposés précédemment, et je me bornerai à faire connaître que le devis des dépenses à faire pour l'installation et la fourniture des appareils de chauffage et de fumisterie ne s'élevait pas, pour :

Un hôpital de seize lits, répartis dans deux salles, à plus de. . . . . . . . . . . . . . . . . . 200 fr. par lit.

Un hôpital de vingt lits, répartis dans deux salles, à plus de. . . . . . . . . . . . . . . . . 180 fr. —

Un autre projet, pour un hôpital des mêmes proportions, dans des localités où le prix du combustible permettrait l'emploi des cheminées ventilatrices, dont les effets ont été étudiés au Conservatoire, et qui sont décrites dans le n° 18 des *Annales* de cet établissement, comprenait, outre les cheminées établies dans chaque salle, un calorifère général à air chaud destiné au chauffage des corridors, des abords et des escaliers. Le devis total de

la dépense de fourniture et d'installation des appareils ne montait qu'à 120 fr. environ par lit.

L'on voit, par l'ensemble de ces études, que le chauffage et la ventilation des hôpitaux peuvent être obtenus, soit dans les établissements existants, soit dans ceux qui seraient à construire, avec des dépenses beaucoup moindres que celles auxquelles ils ont donné lieu à une époque où la question avait été moins étudiée et où l'art n'avait pas encore des règles assez bien établies d'après les données de l'expérience.

En terminant, je crois devoir rappeler que les travaux de maçonnerie relatifs à l'établissement des grandes cheminées et des conduits principaux ne sont pas compris dans les estimations précédentes, mais que, quand pour des constructions nouvelles on aura soin d'exécuter ces travaux en même temps que l'édifice principal, la dépense qu'ils occasionneront sera relativement peu considérable. A. M.

# FLAMBAGE
# DES BOIS ET DES ROCHES,

Par M. A. PAYEN.

Dans un article précédent sur l'assainissement des vaisseaux et la conservation des charpentes, le 19 janvier dernier (n° 19 de ce recueil), nous avons décrit, page 373, un appareil inventé et construit par M. Hugon en vue de réaliser en grand avec économie la méthode du flambage des bois de M. de Lapparent[1]. Pour satisfaire aux demandes qui nous ont été faites et rendre plus facile à comprendre cette description, à laquelle d'ailleurs nous n'avons rien à changer, nous donnons ici le dessin exact de cet appareil, avec la légende explicative des pièces qui le composent; nous y avons ajouté une innovation du même auteur qui rend plus rapide, plus facile et plus économique de main-

1. Paris, 26 avril 1865.

« Monsieur,

« J'ai lu avec un vif intérêt le remarquable travail que vous avez publié dans le dernier numéro des *Annales du Conservatoire des arts et métiers*, sur la conservation des bois ouvrés par une légère carbonisation de leurs faces. Je suis très-heureux de l'approbation que vous avez bien voulu donner aux procédés dont j'ai fait la première application, dans les arsenaux de la marine, à la coque de nos frégates cuirassées; mais je crois devoir vous déclarer, afin de laisser à chacun ce qui lui appartient, que le *chalumeau à houille*, imaginé par M. Hugon, n'est pas seulement une ingénieuse modification du cubilot à air forcé qui figure dans mon Mémoire sur le dépérissement des bois. Un examen attentif de ce chalumeau, tel qu'il fonctionne avec tant de succès en ce moment, m'a démontré qu'il y avait une différence fondamentale entre les deux appareils, et que l'idée de M. Hugon, qu'il n'a rendue pratique qu'à la suite de longs essais et de beaucoup de dépenses, est originale et lui appartient en propre.

« Je vous serais très-obligé si vous vouliez bien faire insérer cette rectification dans le prochain numéro des *Annales*.

« Veuillez agréer, Monsieur, l'expression de mes sentiments de haute considération,

« De Lapparent. »

# COMMUNICATION

RELATIVE A LA

# VENTILATION

PAR L'AIR COMPRIMÉ

Paris. — Imprimerie Bourdier, Capiomont fils aîné et Ce, rue des Poitevins, 6.

SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE

Séances des 15 février, 1er et 15 mars 1867.

# COMMUNICATION

RELATIVE A LA

# VENTILATION

## PAR L'AIR COMPRIMÉ

**1° PAR M. PIARRON DE MONDESIR**

INGÉNIEUR DES PONTS ET CHAUSSÉES

THÉORIE — EXPÉRIENCES

APPLICATION EN COURS D'EXÉCUTION AU PALAIS DE L'EXPOSITION UNIVERSELLE DE 1867

APPLICATIONS A LA MÉTALLURGIE

AUX HOPITAUX, — AUX THÉATRES, — AUX NAVIRES,

A LA SOUFFLERIE DES FORGES

**2° PAR M. LEHAITRE**

APPLICATION A LA VENTILATION DES MINES

PARIS

LIBRAIRIE SCIENTIFIQUE, INDUSTRIELLE ET AGRICOLE

**Eugène LACROIX, Éditeur**

Libraire de la Société des Ingénieurs Civils

QUAI MALAQUAIS, 15

1867

# COMMUNICATION

RELATIVE

# AU SYSTÈME DE VENTILATION PAR L'AIR COMPRIMÉ

ET A SON APPLICATION

## Au Palais de l'Exposition Universelle de 1867.

Par M. **PIARRON de MONDESIR.**

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*EXTRAIT des Mémoires de la Société des Ingénieurs civils.*

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Je vais exposer le système de ventilation par l'air comprimé dont nous nous occupons, MM. Lehaître, Jullienne et moi, depuis bientôt deux années et décrire l'application de ce système actuellement en voie d'exécution au Palais de l'Exposition universelle de 1867.

Aucune publication de nature technique n'a encore été faite relativement au nouveau système dont il s'agit.

Quelques journaux en ont déjà parlé; mais le journal *le Temps* est le seul qui jusqu'à présent ait publié quelque chose de sérieux à ce sujet.

Je me propose d'exposer moi-même, avec tous les développements convenables, la partie théorique et expérimentale de notre système dans un ouvrage spécial dont j'ai déjà préparé tous les éléments, et que je ferai paraître dès que les procès-verbaux et les résultats des expériences faites dans la grande cheminée de ventilation des amphithéâtres du Conservatoire des arts et métiers auront été eux-mêmes publiés.

En attendant, je vais avoir l'honneur de vous soumettre un résumé sommaire de la théorie du nouveau système, ainsi que les principaux résultats des expériences faites jusqu'à ce jour.

Je terminerai cet exposé par une description de l'application qui se prépare au Palais du Champ de Mars.

J'ai pensé que quelques expériences démonstratives auraient pour vous quelque intérêt. Nous les avons préparées; elles viendront en temps et lieu.

Avant de parler de la nouvelle application de l'air comprimé à la ventilation, je vous demanderai la permission, Messieurs, de dire quelques

mots des deux principaux systèmes de ventilation actuellement en usage ; c'est-à-dire la ventilation par l'appel direct de la chaleur, et celle due à l'action directe du ventilateur mécanique.

### VENTILATION PAR APPEL DIRECT DE LA CHALEUR.

Vous connaissez tous, Messieurs, cet effet de ventilation qui n'est autre que celui qui se manifeste dans nos cheminées d'appartement.

Je me propose d'en résumer ici la théorie d'une manière fort succincte; et je renverrai pour plus amples informations aux ouvrages de M. Peclet, et surtout aux *Études sur la ventilation* de M. le général Morin.

Si l'on considère une cheminée, ou conduit vertical, disposée de façon à ce que l'air puisse rentrer plus ou moins librement par la partie inférieure, il est évident d'abord qu'il n'y aura aucune raison pour qu'un courant d'air se manifeste dans cette cheminée, soit de bas en haut, soit de haut en bas, si la température de l'air est la même au bas de l'appareil, à son sommet et dans tout son parcours.

Mais si, par un moyen de chauffage quelconque, on élève la température de l'air dans l'intérieur de la cheminée, l'air extérieur conservant la même température en bas et en haut, tout le monde sait qu'un courant ascendant se produira, et qu'il y aura par conséquent un entraînement d'air plus ou moins considérable.

La cheminée sera alors transformée en appareil de ventilation.

C'est ce qu'on nomme *la ventilation par appel direct de la chaleur.*

On remarquera tout d'abord qu'un tel appareil peut parfaitement servir à extraire de l'air d'un lieu quelconque, mais qu'il ne peut être employé à refouler de l'air frais dans une salle, attendu que dans ce système l'air ne peut être entraîné qu'à la condition d'être échauffé.

La vitesse que l'air prend dans l'appareil de ventilation par appel est évidemment fonction de la différence $\theta$ de température de l'air dans l'intérieur de la cheminée et de l'air extérieur au sommet de la cheminée.

La théorie et l'expérience ont démontré que cette vitesse était proportionnelle à $\sqrt{\theta}$.

Si donc on désigne par $u$ la vitesse par 1″ de l'air à son passage dans la cheminée supposée cylindrique, on aura l'équation :

$$n = A' \sqrt{\theta}. \qquad (1)$$

A′ étant un coefficient toujours plus petit que l'unité et dont la valeur variera avec les dispositions de chaque appareil.

Il est essentiel de remarquer que l'exactitude de cette formule pratique repose sur l'hypothèse d'une égalité parfaite entre la température de l'air aspiré à la base de la cheminée et de l'air extérieur qui entoure le sommet de la cheminée, de telle sorte que si l'on supprimait la source de chaleur

à laquelle est due l'augmentation de température $\theta$, aucun courant ne se produirait dans l'appareil.

On reconnaît *à priori* et à l'inspection seule de cette formule pratique que le système de ventilation par appel doit être très-économique, au point de vue de la dépense de combustible, pour de petites vitesses, et très-dispendieuse au contraire pour de grandes vitesses.

Il est du reste facile de démontrer que cette dépense de combustible *croît proportionnellement au cube de la vitesse.*

Soient :

$\omega$ la section en mètres carrés de la cheminée supposée cylindrique ;

$\delta$ le poids d'un mètre cube d'air au moment où il entre dans la cheminée pour y être échauffé et entraîné ;

$\gamma$ la chaleur spécifique de l'air à pression constante ;

M le nombre de calories communiquées à l'air, à son passage dans la cheminée, par chaque unité de combustible employé pour produire l'augmentation de température $\theta$ ;

$n'$ le nombre des unités de combustible dépensé par heure.

Il est évident que le nombre de calories totales communiqué à l'air à son passage dans la cheminée, pendant la durée d'une heure, est représenté d'une part :

par la quantité $$M \times n' ;$$

et d'autre part par la quantité :

$$\omega \times 3{,}600 \times u \times \theta \times \delta \times \gamma ;$$

On peut donc poser l'égalité :

$$E \times u \times \theta \times \delta \times \gamma = M \times n' \qquad (2)$$

en faisant :

$$\omega \times 3{,}600 = E.$$

Je remplace dans cette équation $\theta$ par sa valeur $\frac{u^2}{A'^2}$ tirée de l'équation (1), et j'obtiens la relation :

$$\frac{E u^3}{n'} = \frac{M \times A'^2}{\delta \times \gamma}. \qquad (3)$$

Dans cette équation, les quantités E, $A'^2$, $\delta$ et $\gamma$ sont évidemment constantes pour un même appareil.

La quantité M peut être également considérée comme constante dans certaines limites.

Cela revient à admettre que, dans certaines limites de consommation de combustible, la quantité de chaleur utilisée par chaque unité de combustible, au profit de l'échauffement de l'air entraîné, restera la même.

Il en résulte que le rapport $\frac{u^3}{n'}$ est constant. Ce que je me proposais de démontrer.

On peut donc énoncer sous forme de théorème pratique la proposition suivante :

*Dans un appareil quelconque de ventilation par appel, la dépense de combustible est proportionnelle au cube de la vitesse d'entraînement.*

La quantité $\frac{Eu^3}{n'}$ qui n'est autre que le nombre de mètres cubes d'air entraîné dans la cheminée, à la vitesse d'un mètre, par chaque unité de combustible consommé, est une *constante* qui donne la mesure de la puissance d'entraînement d'un appareil quelconque de ventilation par appel direct de la chaleur.

Si je désigne cette *constante* par C′, je puis poser :

$$\frac{Eu^3}{n'} = C'. \tag{4}$$

Le volume d'air entraîné à la vitesse $u$ par chaque unité de combustible sera donné par l'équation :

$$\frac{Eu}{n'} = \frac{c'}{u^2}. \tag{5}$$

On peut déterminer la valeur de cette *constante* C′ par un série d'expériences et même par une seule expérience de quelque durée.

Vous savez tous, Messieurs, que la grande cheminée de ventilation des amphithéâtres du Conservatoire peut être citée comme un des appareils les mieux compris pour l'entraînement de l'air par l'action directe de la chaleur.

La *constante* C′ y acquiert une valeur d'environ 2,700. En d'autres termes, chaque kilogramme de charbon consommé dans le foyer établi à la base de cette cheminée y détermine l'entraînement d'environ 2,700 mètres cubes d'air à la vitesse d'un mètre, indépendamment de l'action de la ventilation naturelle.

La valeur de E correspondante au diamètre moyen de la cheminée qui est de $2^m.35$, étant de 15,880, il en résulte qu'il suffit d'une consommation moyenne d'environ $5^k.90$ de charbon pour extraire des amphithéâtres un volume d'air de 15,880 mètres cubes par heure.

C'est assurément un beau résultat qui est dû à l'excellente disposition de l'appareil dont les grandes sections permettent d'entraîner un grand volume d'air à de petites vitesses.

La loi pratique que je viens d'établir par le calcul relativement à la dépense de combustible et à la vitesse d'entraînement se trouve vérifiée par des expériences faites par M. le général Morin lui-même.

Je veux parler ici d'une série d'expériences au nombre de huit faites

dans la cheminée de la direction du Conservatoire, et dans lesquelles le gaz d'éclairage a été employé comme source de chaleur.

Ces expériences sont relatées dans l'ouvrage de M. le général Morin, *Études sur la ventilation*, 1er volume, page 315. Elles remontent aux mois d'août et septembre 1862.

Voici un tableau résumé de ces expériences :

| Numéros des Expériences. | VITESSES observées. $u$ | CUBES de ces vitesses. $u^3$ | MÈTRES CUBES de gaz consommés par heure $n$ | RAPPORT $\frac{u^3}{n}$ |
|---|---|---|---|---|
| | m. | | mèt. cub. | |
| 1 | 1.92 | 7.08 | 0.218 | 32.5 |
| 2 | 2.65 | 18.61 | 0.333 | 55.8 |
| 3 | 2.72 | 20.12 | 0.967 | 20.8 |
| 4 | 3.95 | 61.63 | 2.636 | 23.4 |
| 5 | 3.46 | 41.42 | 2.000 | 20.7 |
| 6 | 3.84 | 56.62 | 2.500 | 22.6 |
| 7 | 4.16 | 71.99 | 3.000 | 23.9 |
| 8 | 4.34 | 81.75 | 3.478 | 23.4 |

Moyenne des six dernières expériences. . . . . . . . . 22.8

En laissant de côté les deux premières expériences faites avec de petites quantités de gaz, et qui paraissent anormales, on voit que les six dernières donnent des résultats assez concordants en ce qui concerne le rapport $\frac{u^3}{n}$ qui varie entre 20.7 et 23.9 et dont la moyenne est 22.8.

Si on tient compte de *l'aléa* des expériences de ventilation, on verra dans ce résultat une vérification assez remarquable de la loi pratique déduite précédemment du calcul.

La théorie et l'expérience s'accordent donc pour démontrer que dans un appareil de ventilation par appel direct de la chaleur, *la dépense du combustible croît proportionnellement au cube de la vitesse d'entraînement.*

En résumé, ce système de ventilation n'est applicable qu'à l'extraction de l'air vicié d'une salle, et il n'est réellement avantageux qu'avec de petites vitesses d'entraînement. Son application exige donc des galeries et cheminées présentant de grandes sections.

D'après les principes de la théorie mécanique de la chaleur, toutes les calories conservées par l'air expulsé au moment où il atteint le sommet de la cheminée de ventilation, constituent une force perdue. La force motrice employée à l'entraînement de l'air consiste donc seulement dans la différence entre la somme des calories communiquées à l'air par le

foyer installé à la base de la cheminée et celle que cet air conserve au sommet de la cheminée.

De cette simple observation découlent deux conséquences importantes :

1° Il est nécessaire de donner une grande hauteur aux cheminées de ventilation, afin que l'air puisse se refroidir le plus possible dans son trajet vertical par la cheminée ;

2° Au fur et à mesure que la vitesse augmente, le refroidissement est relativement moins considérable, et la proportion de chaleur conservée par l'air expulsé, c'est-à-dire la déperdition de force, va en augmentant rapidement.

Je terminerai cet exposé par une dernière remarque :

Le problème de la ventilation comporte évidemment deux termes : extraction de l'air vicié et introduction de l'air nouveau.

Le système de l'appel ne résout que le premier, sauf le cas où l'air nouveau à introduire est chauffé par un calorifère.

Ce système n'est donc pas complet en ce sens qu'il ne peut assurer la rentrée de l'air nouveau.

Il y a des cas, il est vrai, comme aux amphithéâtres du Conservatoire, où la rentrée de l'air nouveau s'effectue librement et sans qu'on ait besoin de recourir à aucun moyen artificiel pour le refoulement de cet air. Ainsi, au grand amphithéâtre du Conservatoire, l'air nouveau rentre par des rosaces pratiquées dans le plafond ; il est pris dans un vaste grenier communiquant avec l'air extérieur par une large ouverture. Dans de telles conditions, la rentrée de l'air nouveau est immédiate et cet air n'a aucune résistance à vaincre dans son parcours, si ce n'est toutefois l'action de la ventilation naturelle de la salle.

Mais il n'en est pas de même dans une foule d'applications, et notamment aux nouveaux théâtres Lyrique et du Châtelet, où l'air nouveau pris à l'extérieur est obligé, pour rentrer dans la salle par les ouvertures ménagées à cet effet, d'effectuer un parcours plus ou moins long dans une suite de galeries ou de gaînes. Cette rentrée d'air étant loin d'être immédiate, comme aux amphithéâtres du Conservatoire, ne fonctionne pas à beaucoup près avec la régularité et l'énergie qu'on espérait. Aussi l'air nouveau rentre-t-il de préférence par les portes des loges, ce qui est un grave inconvénient pour les spectateurs.

Je ne m'étendrai pas davantage sur le système de ventilation par appel direct de la chaleur, et je dirai maintenant quelques mots sur les effets de ventilation obtenus avec des ventilateurs mécaniques.

## VENTILATEURS MÉCANIQUES.

Vous connaissez tous, Messieurs, cet appareil qui aspire l'air par le

centre et l'expulse par la circonférence avec une vitesse plus ou moins grande.

Avec un ventilateur simple, la vitesse de sortie initiale reste en général au-dessous de 50 mètres par 1″, ce qui correspond à une pression de $0^m.13$ d'eau.

Avec le ventilateur double inventé récemment par M. Perrigault, ingénieur-constructeur à Rennes, on peut atteindre une vitesse initiale de 105 à 110 mètres correspondante à des pressions d'eau de $0^m.75$ à $0^m.80$.

Quand le ventilateur est employé comme machine soufflante, toute la puissance du jet d'air comprimé fourni par l'appareil est utilisée.

Mais il n'en est plus de même quand on emploie cet appareil pour produire un effet de ventilation. L'appareil peut alors procéder par refoulement ou par aspiration.

Dans le premier cas, comme on ne peut pas pratiquement introduire de l'air dans une salle avec des vitesses de 50 mètres, il faut nécessairement faire détendre l'air comprimé par le ventilateur dans des conduites dont on calcule la section de manière à ce que les rentrées d'air s'effectuent avec la vitesse admise pour la ventilation, c'est-à-dire avec des vitesses de 1 à 2 mètres par seconde.

L'air fourni par l'appareil est alors condamné à une détente stérile pour passer de la vitesse initiale à la vitesse de ventilation.

Au point de vue mécanique, l'opération est loin d'être bonne. On peut la comparer à celle qui consisterait à remonter au premier étage un volume d'eau destiné aux besoins du rez-de-chaussée.

Il y a évidemment, dans cette manière d'opérer, une perte de force qui est d'autant plus grande que l'écart entre la vitesse initiale et la vitesse finale de ventilation est lui-même plus considérable.

Dans le cas où l'appareil procède par extraction, l'inconvénient d'une rentrée d'air à grande vitesse n'existe plus, il est vrai; mais il y a toujours une perte de force plus ou moins considérable provenant de ce que l'air expulsé est lancé dans l'atmosphère avec une grande vitesse.

Ces observations nous amènent naturellement à la conclusion suivante : c'est que les ventilateurs mécaniques destinés à la ventilation doivent être établis de manière à diminuer autant que possible leur vitesse initiale.

Il convient donc d'augmenter leur diamètre et de diminuer leur vitesse de rotation; mais alors le rendement de l'appareil diminue.

Je ne crois pas inutile de faire remarquer ici que j'entends par le rendement d'un ventilateur mécanique, et en général de tout appareil de compression, le rapport entre la force vive du jet, sortant de l'appareil exprimé en chevaux-vapeur, et le nombre de chevaux-vapeur développé par le moteur qui actionne l'appareil.

Pour le ventilateur double de M. Perrigault, ce rendement peut approcher de 50 p. 100.

Pour les ventilateurs simples, ce rendement est beaucoup moindre.

Je dois vous avouer du reste que je n'ai pas encore pu me procurer de renseignements précis sur cette question.

Toutefois la communication faite ici, à la dernière séance, par M. Monthiers, me met à même de calculer le rendement d'un ventilateur mécanique, cité par cet ingénieur.

Je veux parler du ventilateur à force centrifuge de $1^{m}.70$ de diamètre et débitant $4^{mc}.57$ à la pression du $0^{m}.02$ d'eau par $1''$, pour une consommation de 580 kilog. de charbon par 24 heures.

On a estimé l'effet utile en chevaux-vapeur à $1^{c}.27$, et la force motrice dépensée à $4^{c}.70$, d'où l'on conclut au rendement de 27 p. 100.

Je crois ce calcul entaché d'erreur.

En effet, la force en chevaux-vapeur d'un jet à la pression, de $0^{m}.02$ d'eau et débitant $4^{mc}.57$ par $1''$, est bien de $1^{c}.27$. Mais une consommation de 580 kilog. de charbon par 24 heures, soit de $24^{k}.17$ par heure, correspond, à raison de $2^{k}.50$ par force de cheval et par heure, à une force motrice de $9^{c}.67$ et non pas de $4^{c}.70$.

Il en résulte que le rendement du ventilateur ne serait que de 13 p. 100 au lieu de 27 p. 100.

Vous savez, Messieurs, qu'il existe des applications de ventilateurs mécaniques à la ventilation. J'en citerai deux seulement :

Celle de l'hôpital Lariboisière, pavillons des hommes, et celle du théâtre des Célestins à Lyon.

A l'hôpital Lariboisière l'air extérieur est refoulé dans la salle des trois pavillons des hommes par un ventilateur mécanique mis en mouvement par une machine à vapeur. Je renverrai, pour la description des appareils et les nombreuses expériences faites, aux *Études sur la ventilation*, de M. le général Morin, 1er volume, page 356 et suivantes.

Je vais me borner à l'énonciation des principaux résultats :

1° L'air refoulé pénètre dans la salle par des poêles installés sur la ligne centrale ;

2° La vitesse de rentrée de l'air nouveau par ces poêles varie entre $0^{m}.60$ et 1 mètre;

3° Le volume d'air débité par heure par les poêles est d'environ 30,000 mètres cubes pour un developpement de force du moteur de 10 chevaux.

On obtient donc ainsi un refoulement d'environ 3,000 mètres cubes par force de cheval, soit de 1,200 mètres cubes par kilogramme de charbon, en admettant une consommation de charbon de $2^{k}.50$ par cheval et par heure.

Ce résultat est inférieur à celui des amphithéâtres du Conservatoire que j'ai cité plus haut.

M. le général Morin, dans son ouvrage déjà cité, a calculé le prix de la ventilation annuelle à raison d'un mètre cube par heure, y compris intérêts et amortissement du capital, pour diverses installations.

Il constate ainsi :

1° Que pour les pavillons des hommes de l'hôpital Lariboisière ventilés mécaniquement, le prix de revient est de . . . . . . . . . . . 2 fr. 43

2° Que ce même prix, pour les pavillons des femmes, ventilés par appel direct de la chaleur, n'est que de. . . . . . . . . . 1 43

Ce qui correspond à 0 fr. 28 par mille mètres cubes pour le premier cas, et à 0 fr. 16 pour le second.

Ces résultats sont une nouvelle preuve de l'infériorité du système de ventilation mécanique relativement au système de l'appel.

Je passe maintenant au théâtre des Célestins de Lyon.

On a installé dans la cave de ce théâtre une turbine de la force de 2 chevaux qui active un ventilateur mécanique.

On obtient ainsi un refoulement d'air dans la salle qui a été évalué à environ 1,800 mètres cubes par heure, par une commission instituée *ad hoc*.

Malgré la faiblesse de cet effet de ventilation, on a constaté une amélioration sensible dans l'état atmosphérique de cette salle.

Ce résultat correspond à 900 mètres cubes par cheval, soit à 360 mètres cubes par kilogramme de charbon.

Il serait donc notablement inférieur à celui constaté ci-dessus pour l'hôpital Lariboisière.

Je ne crois pas utile d'entrer dans de plus grands détails sur la ventilation mécanique; et je vais aborder maintenant le nouveau système de ventilation par l'air comprimé.

## VENTILATION PAR L'AIR COMPRIMÉ.

Messieurs, vous voyez devant vous un petit appareil de ventilation par l'air comprimé.

Il se compose d'un tuyau en fer blanc de $0^m.20$ de diamètre et de $1^m.20$ de longueur, terminé par un pavillon.

A l'extrémité qui porte le pavillon, et dans la direction de l'axe du tuyau, est fixé un tube de petit diamètre communiquant avec un récipient d'air comprimé.

Un pas de vis permet de fixer au bout de ce tube des ajutages de différents diamètres.

L'air comprimé qui sortira par l'ajutage, va former par sa détente un véritable piston gazeux qui poussera devant lui l'air contenu dans le tuyau. Cet air sera remplacé par de l'air nouveau entrant par le pavillon; et un courant général plus ou moins rapide va se manifester dans toute la section de tuyau.

L'air comprimé joue ici le rôle de moteur direct et entraîne avec lui une masse plus ou moins considérable d'air atmosphérique.

Je désigne :

Par $m$ la masse d'air comprimé qui sort par 1″ de l'ajutage ;

Par V la vitesse de cet air ;

Par U la vitesse du courant d'air qui se produit dans le tuyau en avant du jet ;

Par M la masse d'air qui sort du tuyau par 1″.

Toute la théorie de la ventilation par l'air comprimé est basée sur l'équation suivante :

$$mV = MU. \tag{1}$$

Je désigne maintenant :

Par $d$ le diamètre de l'ajutage ;

Par D celui du tuyau ;

Par $\pi$ la pression atmosphérique $= 10{,}334^k$ ;

Par $g$ la force accélératrice de la pesanteur $= 9^m.81$ ;

Par $\delta$ le poids d'un mètre cube d'air atmosphérique ;

Par $\mu$ le nombre d'atmosphères effectives de la compression de l'air moteur.

J'aurai les relations :

$$mV = 2 \times \frac{\pi d^2}{4} \times \mu \times \pi;$$

et

$$MU = \frac{\pi D^2}{4} \times \frac{\delta}{g} \times U^2;$$

j'en tire immédiatement l'équation :

$$U = \sqrt{\frac{2\pi g}{\delta}} \times \frac{d}{D} \times \sqrt{\mu}. \tag{2}$$

Pour des vitesses d'entraînement ne dépassant pas 30 à 40 mètres et pour la même température, on peut, sans erreur sensible, considérer $\delta$ comme constant.

Alors la quantité

$$\sqrt{\frac{2\pi g}{\delta}}$$

sera un coefficient constant que je désignerai par A$o$.

Pour la valeur $\delta = 1^k.24$ qui correspond à la température de 12° moyenne générale de la France et à la pression barométrique de $0^m.76$, on aura :

$$Ao = \sqrt{\frac{2 \times 10,\ 334 \times 9.81}{1.24}} = 404.4.$$

J'écrirai donc désormais :

$$U = Ao \times \frac{d}{D} \times \sqrt{\mu} = 404.4 \times \frac{d}{D} \times \sqrt{\mu}. \tag{3}$$

Telle est l'équation qui donne la vitesse d'entraînement dans l'appareil qui est devant vous et que j'appelle *appareil simple*, parce que la conduite dans laquelle se fait l'entraînement présente un minimum de longueur, et que je puis y négliger l'influence des frottements.

Cette équation suppose que les coefficients de contraction de l'air comprimé à sa sortie de l'ajutage et de l'air atmosphérique à sa rentrée par le pavillon sont égaux ; ce qui a sensiblement lieu dans la pratique.

L'exactitude de la formule (3) a été vérifiée par une série d'expériences faites avec le concours de M. Paul de Mondesir, ingénieur en chef des manufactures de l'État, et de mes collaborateurs MM. Lehaître et Jullienne.

Je joins ici le tableau de ces expériences, au nombre de 36.

La pression de l'air comprimé moteur a varié dans des limites comprises entre $0^a.20$ et $8^a.85$.

Le diamètre des ajutages a varié entre $0^m.0003$ et $0^m.0025$.

Le tuyau qui a servi aux expériences est celui qui est ici devant vous.

Je ne présente pas cette série d'expériences comme ayant été faites avec toute la précision désirable en pareille matière.

Mais la comparaison des vitesses données par l'anémomètre avec celles calculées par la formule (3) ne doit laisser aucun doute sur l'exactitude de cette formule.

En effet, les différences ont varié tantôt en plus, tantôt en moins.

On a observé 15 différences en moins, sur la vitesse théorique, dont la moyenne est de 3 %, et 21 différences en plus dont la moyenne est de 6 %.

La théorie est évidemment ici d'accord avec l'expérience.

Nous allons maintenant faire quelques expériences en votre présence avec une pompe à air et un récipient que M. Wiessnegg, fabricant d'appareils, a bien voulu mettre à notre disposition.

*Tableau des expériences faites le 2 février 1866, dans une conduite en fer-blanc de* 0$^{m}$.20 *de diamètre et de* 1$^{m}$.20 *de longueur.*

| Numéros des expériences. | PRESSIONS moyennes dans le récipient. | NOMBRE de tours de l'anémomètre. | VITESSES observées. | VITESSES calculées. | DIFFÉRENCES. |
|---|---|---|---|---|---|
| 1° Ajutage de 0$^{m}$.0005. Durée de l'expérience 1′. | | | | | |
| | a. | | m. | m. | |
| 1 | 8.85 | 875 | 1.76 | 1.80 | —0.04 |
| 2 | 8.45 | 850 | 1.71 | 1.76 | —0.05 |
| 3 | 8.30 | 845 | 1.70 | 1.74 | —0.04 |
| 4 | 8.20 | 775 | 1.55 | 1.73 | —0.18 |
| 5 | 8.08 | 750 | 1.52 | 1.72 | —0.20 |
| 2° Ajutage de 0$^{m}$.0005. Durée de l'expérience 1′. | | | | | |
| 6 | 7.85 | 1,425 | 2.81 | 2.83 | —0.02 |
| 7 | 7.70 | 1,375 | 2.72 | 2.80 | —0.08 |
| 8 | 7.55 | 1,375 | 2.72 | 2.77 | —0.05 |
| 9 | 7.50 | 1,325 | 2.61 | 2.76 | —0.14 |
| 10 | 7.45 | 1,350 | 2.65 | 2.75 | —0.10 |
| 3° Ajutage de 0$^{m}$.0007. Durée de l'expérience 1′. | | | | | |
| 11 | 7.17 | 1,920 | 3.76 | 3.78 | —0.02 |
| 12 | 6.45 | 1,950 | 3.82 | 3.59 | +0.23 |
| 13 | 6.30 | 1,925 | 3.77 | 3.54 | +0.23 |
| 14 | 6.05 | 1,850 | 3.62 | 3.47 | +0.16 |
| 15 | 5.80 | 1,825 | 3.58 | 3.40 | +0.18 |
| 4° Ajutage de 0$^{m}$.0009. Durée de l'expérience 1′. | | | | | |
| 16 | 5.42 | 2,200 | 4.30 | 4.23 | +0.07 |
| 17 | 5.08 | 2,175 | 4.25 | 4.09 | +0.16 |
| 18 | 4.78 | 2,075 | 4.06 | 3.97 | +0.09 |
| 19 | 4.50 | 1,960 | 3.84 | 3.85 | —0.01 |
| 20 | 4.20 | 2,000 | 3.91 | 3.72 | +0.19 |
| 5° Ajutage de 0$^{m}$.0001. Durée de l'expérience 1′. | | | | | |
| 21 | 3.85 | 2,140 | 4.18 | 3.96 | +0.21 |
| 22 | 3.58 | 2,050 | 4.01 | 3.81 | +0.20 |
| 23 | 3.10 | 1,875 | 3.67 | 3.55 | +0.12 |
| 6° Ajutage de 0$^{m}$.0012. Durée de l'expérience 1′. | | | | | |
| 24 | 2.80 | 2,200 | 4.30 | 4.05 | +0.25 |
| 25 | 2.45 | 2,000 | 3.91 | 3.79 | +0.12 |
| 26 | 2.15 | 1,880 | 3.68 | 3.55 | +0.13 |
| 7° Ajutage de 0$^{m}$.0015. Durée de l'expérience 30″. | | | | | |
| 27 | 1.88 | 1,175 | 4.58 | 4.15 | +0.43 |
| 28 | 1.68 | 1,130 | 4.41 | 3.92 | +0.49 |
| 29 | 1.53 | 950 | 3.72 | 3.74 | —0.02 |
| 30 | 1.35 | 950 | 3.72 | 3.52 | +0.20 |
| 8° Ajutage de 0$^{m}$.0018. Durée de l'expérience 30″. | | | | | |
| | a. | | m. | m. | |
| 31 | 1.13 | 950 | 3.72 | 3.85 | —0.13 |
| 32 | 0.90 | 830 | 3.27 | 3.44 | —0.17 |
| 33 | 0.70 | 830 | 3.27 | 3.04 | +0.13 |
| 34 | 0.55 | 750 | 2.96 | 2.69 | +0.27 |
| 9° Ajutage de 0$^{m}$.0025. Durée de l'expérience 30″. | | | | | |
| 35 | 0.40 | 925 | 3.62 | 3.19 | +0.43 |
| 36 | 0.20 | 650 | 2.57 | 2.25 | +0.32 |

## OBSERVATIONS.

La température de la salle d'expériences était de 11° 1/2.

La pression dans le récipient était donnée par un manomètre métallique Bourdon. On prenait la moyenne des pressions au commencement et à la fin de chaque expérience.

La formule de l'anémomètre était :

$$V = 0.08 + 0.115\,n.$$

On le promenait sur le pourtour du tube de 0$^{m}$.20. La vitesse variait généralement suivant la position de l'instrument. Cela tenait à ce que les ajutages n'étaient pas toujours parfaitement dirigés suivant l'axe de la conduite. C'est à cette cause qu'on doit attribuer les anomalies qui se présentent parfois dans le nombre de tours observés.

Les diamètres des ajutages doivent être considérés comme parfaitement exacts, malgré leur exiguïté. Ils ont été faits par M. Teigny, opticien, et vérifiés au moyen de calibres ou aiguilles dont les diamètres ont été vérifiés à leur tour au compas Palmer.

Dans les expériences précédentes, le tuyau de 0$^{m}$.20 n'était pas muni de pavillon.

La formule (3) donne immédiatement lieu à une remarque des plus importantes. C'est qu'on peut obtenir la même vitesse d'entraînement dans le même appareil, soit en faisant varier la pression, soit en faisant varier le diamètre de l'orifice d'échappement du jet comprimé moteur, pourvu que le produit $d\sqrt{\mu}$ reste le même.

Ainsi, dans les expériences n$^{os}$ 11 et 31 du tableau, on a constaté sensiblement la même vitesse d'entraînement ($3^m.76$ et $3^m.72$) avec des pressions de $7^a.17$ et de $1^a.13$, et avec des ajutages de $0^m.0007$ et de $0^m.0018$ de diamètre.

Mais les forces motrices en chevaux-vapeur de ces deux jets sont bien différentes, ainsi que je vais le démontrer.

Soient V et V′ les vitesses de sortie des deux jets d'air comprimé aux pressions effectives $\mu$ et $\mu'$, s'échappant par des orifices de diamètres $d$ et $d'$ et produisant le même effet de ventilation dans le même appareil :

On aura d'abord la relation :

$$mV = m'V'.$$

La force motrice en chevaux-vapeur du premier jet sera :

$$\frac{mV^2}{2 \times 75}.$$

Celle du second jet sera :

$$\frac{m'V'^2}{2 \times 75},$$

et leur rapport sera :

$$\frac{V}{V'}.$$

Comme elles produisent le même effet de ventilation, la conclusion est *qu'il y a avantage, au point de vue de la dépense de force motrice, à employer de l'air comprimé à basse pression.*

Je me reporte maintenant à la relation fondamentale :

$$mV = MU.$$

Si je désigne par F la force motrice en chevaux-vapeur du jet d'air comprimé, laquelle est égale à

$$\frac{mV^2}{150},$$

il est clair que je puis poser l'égalité :

$$\frac{MU}{\frac{mV^2}{150}} = \frac{MU}{F} = \frac{150}{V}. \qquad (4)$$

Or, on a :

$$MU = \frac{\omega \times \delta \times U^2}{g} = EU^2 \times \frac{\delta}{g \times 3{,}600};$$

en faisant comme précédemment $E = \omega \times 3{,}600$.

D'un autre côté la relation :

$$Ao = \sqrt{\frac{2g\pi}{\delta}},$$

donne :

$$\frac{\delta}{g} = \frac{2\pi}{Ao^2}.$$

On aura donc en définitive :

$$\frac{MU}{F} = \frac{150}{V} = EU^2 \frac{2\pi}{F \times Ao^2 \times 3,600},$$

et
$$\frac{EU^2}{F} \times V = \frac{150 \times 3,600 \times Ao^2}{2\pi}. \qquad (5)$$

Le second membre de l'équation (5) est une quantité constante que je désignerai par $Co$ et que j'appellerai la *constante générale* de la ventilation par l'air comprimé dans l'appareil simple.

Cette constante n'est autre que le volume d'air entraîné, dans l'appareil simple, à la vitesse d'un mètre par chaque cheval-vapeur du jet, multiplié par la vitesse de sortie de cet air.

En remplaçant, dans l'équation (5) $Ao^2$ et $2\pi$ par leur valeur moyenne :

$$Ao^2 = 163,539$$

et
$$2\pi = 20,668$$

j'obtiens pour la valeur de la constante $Co$.

$$Co = 4,272,840. \qquad (6)$$

Le volume d'air entraîné, dans l'appareil simple, à une vitesse quelconque U, par chaque cheval-vapeur de jet, sera donc donné par la formule :

$$\frac{EU}{F} = \frac{Co}{U \times V}. \qquad (7)$$

Ce volume *varie donc en raison inverse de la vitesse d'entraînement* U *et de la vitesse* V *de l'air comprimé moteur.*

L'équation
$$\frac{EU^2}{F} \times V = Co$$

démontre que la force motrice du jet croît proportionnellement au *carré* de la vitesse d'entraînement, quand la vitesse V de l'air comprimé moteur est la même, ou ce qui revient au même, quand la pression $\mu$ ne varie pas.

Or, la force motrice du jet est une certaine fraction de la force développée par le moteur, et du nombre d'unités de combustible consommé par ce moteur.

Donc la consommation de combustible croît comme le carré de la vitesse dans la ventilation par l'air comprimé, tandis qu'elle croît comme le cube de la même vitesse dans la ventilation par appel.

La théorie que je viens d'exposer est relative à l'entraînement de l'air dans l'*appareil simple*.

Mais il est facile de voir qu'elle s'applique à un appareil quelconque.

Je vais maintenant considérer un appareil quelconque composé d'un premier réseau de conduites dans lequel l'air devra être aspiré, et d'un second réseau dans lequel l'air devra être refoulé.

J'intercalerai l'appareil simple entre ces deux réseaux.

Il est évident que la vitesse d'entraînement $u$ qui se produira, dans ces conditions, dans le trajet de l'appareil simple, sera moindre que la vitesse U donnée par la formule (3).

On sait d'avance par les formules données par les hydrauliciens et en particulier par d'Aubuisson, qui s'est occupé spécialement de l'étude du mouvement de l'air dans les conduites, que l'on aura dans tous les cas que l'on pourra considérer :

$$u = \frac{U}{K}. \tag{8}$$

K étant un coefficient plus grand que l'unité et dont la valeur tient compte de toutes les pertes de force vive dues aux frottements.

Je crois inutile de reproduire ici la théorie de d'Aubuisson qui, comme on le sait, est fondée sur ce principe : que les pertes de charge dues aux frottements dans les conduites sont proportionnelles aux carrés des vitesses et au rapport des longueurs des conduites à leur diamètre.

La vitesse d'entraînement dans un appareil quelconque de ventilation par l'air comprimé sera donc donnée par la formule :

$$u = \frac{Ao}{K} \times \frac{d}{D} \times V\mu. \tag{9}$$

Le coefficient K peut se calculer d'avance d'après les dispositions de l'appareil.

Mais l'expérience directe en donnera toujours plus exactement la véritable valeur.

Si l'on désigne par C la *constante* générale de ventilation dans un appareil dont le coefficient est K, il est clair que l'on aura :

$$C = \frac{Eu^2}{F} \times V = \frac{Co}{K^2};$$

et par suite

$$K = \sqrt{\frac{C}{Co}}. \tag{10}$$

Une seule expérience suffira à la rigueur pour déterminer $u$ et par suite la *constante* C et le coefficient K.

Je ne m'étendrai pas davantage sur la partie théorique du nouveau système de ventilation par l'air comprimé.

Je vais maintenant dire quelques mots des expériences comparatives faites dans la grande cheminée de ventilation du Conservatoire.

EXPÉRIENCES COMPARATIVES DU CONSERVATOIRE.

Ces expériences, qui ont eu lieu en mai et juin de l'année dernière, sont dues à l'initiative de l'honorable et savant général qui dirige ce magnifique établissement.

M. Tresca les a dirigées avec cette impartialité que tout le monde connaît.

On avait installé dans l'axe de la cheminée et à 5 mètres environ au-dessus du fond, un appareil injecteur sur lequel on vissait des ajutages dont le diamètre a varié entre $0^{m}.01$ et $0^{m}.03$. La pression effective des jets a varié entre 2 atmosphères et $0^{a}.13$.

Il a été impossible d'expérimenter avec des pressions plus basses, en raison des petites dimensions de la pompe à air.

On a fait ensuite, comparativement, la grande expérience par le feu dont j'ai déjà eu occasion de parler.

M. Tresca n'a pas encore publié les procès-verbaux de ces expériences. Mais je suis convaincu qu'il ne trouvera pas mauvais que je vous en fasse connaître ici, d'une manière sommaire, les principaux résultats.

Je commencerai par la grande expérience de ventilation par le feu.

Cette expérience, faite les 25 et 26 juin, a donné $32^{h}\,1/2$.

Le feu était réglé de manière à maintenir la vitesse d'entraînement dans la section moyenne de la cheminée aux environs de $1^{m}.45$ par $1''$.

La moyenne de cette vitesse donnée par un anémomètre totalisateur à compteur électrique, a été de $1^{m}.432$.

La consommation totale du charbon a été de $417^{k}.43$, ce qui donne une moyenne de $12^{k}.84$ par heure.

Mais si la vitesse a été maintenue dans des limites assez rapprochées de la moyenne, il n'en est pas de même de la consommation horaire du charbon qui a varié entre $8^{k}.16$ et $20^{k}.41$.

Ces variations notables dans la consommation du combustible par heure tiennent à l'action de la ventilation naturelle.

Si on ne tenait pas compte de cette action, on trouverait pour la valeur de la *constante* C', relative à l'appareil de ventilation du Conservatoire :

$$C' = \frac{Eu^3}{n'} = \frac{15,880 \times (1.432)^3}{12.84} = 3,577.$$

Mais il est évident que l'action de la ventilation naturelle était d'autant plus grande que la consommation de combustible était moindre, et réciproquement.

Pour éliminer autant que possible l'effet de la ventilation naturelle, il paraît convenable de considérer la partie de l'expérience où la consommation du charbon a été le plus active.

Le tableau de cette expérience indique une consommation partielle de

$80^k$ de charbon entre $4^h$ et $8^h45'$ du soir du 25 juin ; ce qui donne pour cet intervalle de $4^h3/4$ une consommation moyenne de $16^k.84$ par heure.

La vitesse moyenne observée pendant la période considérée a été de $1^m.415$.

Si donc, on admet que dans cette période, l'effet de la ventilation naturelle puisse être considéré comme nul ou négligeable, on aura pour la constante C′, une seconde valeur qui sera :

$$C' = \frac{15,880 \times (1.415)^3}{16.84} = 2,671.$$

Il me paraît que cette dernière valeur de la constante C′, que j'ai déjà eu occasion de citer, est celle qui se rapproche le plus de la vérité, parce qu'elle élimine l'action de la ventilation naturelle.

Je la prendrai pour terme de comparaison avec les expériences sur l'air comprimé dont je vais maintenant parler.

Leur nombre est de 33.

Je ferai remarquer tout d'abord que l'application de ce système permet d'observer la ventilation naturelle à un moment quelconque. En effet, la cheminée n'étant pas chauffée, il suffit pour cela d'interrompre l'action du jet moteur.

Il a donc été possible, pour chaque expérience, de faire la correction due à la ventilation naturelle observée.

Cette correction faite, on arrive aux résultats principaux suivants :

1° La moyenne générale de la constante générale C, déduite de 33 expériences, est :

$$C = 1,006,697\,;$$

Ce qui donne pour le coefficient de résistance K relatif à l'appareil du Conservatoire :

$$K = \sqrt{\frac{4,272,840}{1,006,697}} = 2.05\,;$$

2° La moyenne particulière de C relative aux 4 expériences faites à la pression de 2 atmosphères avec l'ajutage de $0^m.01$ est :

$$C = 1,044,367\,;$$

3° La moyenne particulière de C relative aux 5 expériences faites à la pression de $0^a.13$ avec l'ajutage de $0^m.03$ est :

$$C = 1,073,964.$$

Ces deux derniers résultats permettent d'établir une comparaison entre le système de l'appel et le système par l'air comprimé aux pressions extrêmes de 2 atmosphères et de $0^a.13$.

La vitesse de l'air comprimé à 2 atmosphères est 330.

Celle de l'air comprimé à $0^a.13$ est 137.

Nous aurons donc pour le premier cas :

$$\frac{C}{V} = \frac{Eu^2}{F} = \frac{1,044,367}{330} = 3,165\,;$$

et pour le second :

$$\frac{C}{V} = \frac{Eu^2}{F} = \frac{1,073,964}{137} = 7,839.$$

Ainsi, les deux séries d'expériences faites avec les pressions extrêmes, $\mu = 2$ et $\mu = 0.13$, font ressortir un entraînement, à la vitesse de $1^m.00$, et par chaque cheval-vapeur du jet, de $3,165^{mc}$ pour la pression de 2 atmosphères et de $7,839^{mc}$ pour la pression de $0^a.13$.

Pour comparer ces résultats à ceux de la ventilation par le feu, il faut remplacer chaque cheval-vapeur de jet par son équivalent en charbon.

Pour cela, j'estimerai d'abord à $2^k.50$ la consommation horaire de charbon, représentative de cheval-vapeur.

J'estimerai ensuite à 0.60 le rendement d'une bonne pompe à air, fonctionnant dans les limites de pression qui lui conviennent.

J'aurai alors, en désignant par $n$ le nombre de kilogrammes de charbon équivalent à chaque cheval-vapeur de jet :

$$\frac{Eu^2}{n} = \frac{3,165 \times 0.60}{2.50} = 760 \text{ pour } \mu = 2,$$

et

$$\frac{Eu^2}{n} = \frac{7,839 \times 0.60}{2.50} = 1,881 \text{ pour } \mu \times 0.13.$$

Ces résultats représentent le volume entraîné, à la vitesse de $1^m00$, par kilogramme de charbon brûlé. Ils démontrent :

1° Que l'effet de ventilation comparé au développement de la force du moteur, croît au fur et à mesure que la pression de l'air comprimé diminue, indication déjà donnée par la théorie;

2° Qu'à la pression de $2^a$, et même à celle de $0^m.13$, le système de l'air comprimé n'atteint pas le résultat du système de l'appel, dans la grande cheminée du Conservatoire, pour des vitesses d'entraînement, qui ne dépassent pas $1^m.00$ par $1''$.

Mais il ne faut pas oublier que, dans le système de l'appel, la consommation de combustible croît proportionnellement au cube de la vitesse, tandis que dans le système de l'air comprimé elle n'augmente que proportionnellement au carré de la vitesse.

Il y a donc une certaine vitesse d'entraînement $u_0$, pour laquelle les deux systèmes s'équilibrent au point de vue du combustible.

Cette vitesse $u_0$ est donnée par l'équation :

$$\frac{C}{V \times u_0} = \frac{C'}{u_0^{\,3}}. \qquad (11)$$

Appliquons-la pour les valeurs $V = 330$ et $V = 137$, et pour la valeur $C' = 2,671$.

On aura les 2 équations :

pour $\mu = 2 : \dfrac{760}{u_0} = \dfrac{2,671}{u_0^2}$ ; d'où $u_0 = 3^m.51$.

pour $\mu = 0.13 : \dfrac{1,881}{u_0} = \dfrac{2,671}{u_0^2}$; d'où $u_0 = 1.^m42$.

Ces deux vitesses d'équilibre sont sensiblement entre elles dans le rapport des nombres 330 et 137, qui expriment la vitesse de l'air comprimé aux pressions $\mu = 2$ et $\mu = 0.13$, conformément aux indications de la théorie.

On peut donc conclure de là, que si l'appareil de compression qui servait à ces expériences eût permis d'expérimenter utilement des jets à une pression inférieure à $0^a.13$, l'équilibre se serait produit entre les deux systèmes, à des vitesses inférieures à $1^m.00$.

J'ajouterai en terminant que la grande hauteur de la cheminée de ventilation du Conservatoire, sa conicité et la présence d'un foyer massif à la base, sont des circonstances qui étaient évidemment défavorables au fonctionnement du nouveau système, et qui ont dû contribuer à en amoindrir les effets.

Cette situation défavorable m'était connue d'avance; mais je n'ai pas hésité un seul instant à l'accepter, ayant la conviction que des expériences faites sur une grande échelle ne pourraient manquer de mettre en lumière des résultats nouveaux et intéressants.

Je profite de l'occasion qui m'est offerte ici pour remercier MM. les Directeurs du Conservatoire de la libérale hospitalité qu'ils ont bien voulu m'accorder.

### EXPÉRIENCES SUR UN DES SECTEURS DU PALAIS DU CHAMP DE MARS.

Cet essai préalable est dû à l'initiative éclairée de M. Krantz, ingénieur en chef des ponts et chaussées, directeur des travaux du Palais. M. Krantz avait obtenu de la Commission impériale, pour cet essai, un crédit de 3,000 fr. sur lequel 1,200 fr. seulement ont été dépensés.

Je vous demanderai, Messieurs, de vous indiquer sommairement les résultats de cette expérience préalable faite en octobre dernier, sous la direction de M. Tresca.

Je puis le faire avec d'autant plus de liberté que M. Tresca a rédigé depuis longtemps et remis à la Commission impériale son procès-verbal, dont les conclusions favorables ont amené l'application du système à la ventilation générale du Palais.

Vous connaissez probablement, Messieurs, les dispositions des galeries

souterraines d'aérage du Palais, dispositions très-heureusement combinées par M. Krantz en vue d'une ventilation naturelle.

Au pourtour extérieur du Palais règne une grande galerie souterraine divisée par des piliers en trois travées de 3 mètres de largeur chacune.

Une cloison isole complétement les deux travées les plus rapprochées du centre, lesquelles sont affectées comme caves au service des exposants de la classe des aliments. La travée la plus éloignée du centre est réservée comme galerie d'aérage.

Cette galerie communique avec l'air extérieur par 16 puits d'aérage de 3 mètres de diamètre, disposés à peu près symétriquement autour du Palais et à une distance d'environ 20 mètres de la marquise extérieure.

Il y a par conséquent 16 petites galeries souterraines qui réunissent les puits à la grande galerie circulaire d'aérage.

Pour que l'air extérieur, appelé d'abord par les puits dans la galerie d'aérage, puisse pénétrer dans le Palais, M. Krantz a établi 16 galeries rayonnantes correspondantes aux 16 allées rayonnantes du Palais. Il a eu soin toutefois de ne pas placer la galerie souterraine directement au-dessous de l'allée rayonnante, afin que la voûte de cette galerie qui est construite en béton Coignet, et dont l'épaisseur à la clef n'est que de $0^m.15$, n'eut point à supporter les charges des transports. L'axe de la galerie rayonnante est toujours situé à droite de celui de l'allée quand on regarde le centre du Palais.

Chacune des 16 galeries souterraines rayonnantes pénètre sous le Palais sur une longueur de 120 mètres, c'est-à-dire jusqu'à l'allée de circulation la plus voisine du centre.

Vous savez, Messieurs, que ces allées de circulation sont au nombre de 3, et qu'elles sont tracées suivant des circonférences.

Au droit de chacune de ces allées, la galerie souterraine rayonnante présente des branchements circulaires situés immédiatement en dessous des allées de circulation.

Ces branchements ne sont pas continus comme les allées; ils forment impasse, de telle sorte que chaque secteur souterrain composé d'une galerie rayonnante et de trois portions de galeries circulaires se trouve complétement isolé de ses deux voisins et peut être ventilé d'une manière indépendante.

L'ensemble de ces dispositions est complété par l'installation de grilles en bois ou *caillebotis*, qui mettent l'air des galeries souterraines circulaires en communication directe avec les allées de circulation.

Telles sont en substance les dispositions exécutées par M. Krantz dans le but d'aérer le Palais par l'action de la ventilation naturelle.

Cet habile ingénieur avait également en vue, dans l'établissement de ce réseau souterrain à grande section, de pouvoir y placer des conduites d'eau et de gaz et de les faire servir au besoin à la desserte du Palais.

Malgré l'habileté incontestable qui a présidé à ces installations sou-

terraines, je ne sais jusqu'à quel point un effet de ventilation naturelle appréciable se serait produit par les caillebotis. Il est probable que les rentrées d'air auraient eu lieu de préférence par les baies de l'édifice.

Mais il est incontestable que ces dispositions se prêtent pafaitement à une application de ventilation par l'air comprimé. Il suffit, en effet, pour cela, d'installer un jet moteur dans chacune des galeries rayonnantes. Ce jet aspirera l'air de la galerie d'aérage et le refoulera dans le Palais par les *caillebotis* des allées de circulation.

L'air vicié ou échauffé qui tend naturellement à s'élever de bas en haut, sortira par les persiennes ménagées dans la toiture des galeries d'exposition.

Cette description rapide du réseau souterrain du Palais était nécessaire pour l'intelligence des expériences faites et de l'application qui se prépare.

Les expériences ont eu lieu sur le secteur n° 3.

Je me suis proposé, dans cet essai, d'expérimenter des jets d'air comprimé à très-basse pression, et au lieu de prendre la pompe à air qui avait servi aux expériences du Conservatoire, j'ai préféré employer comme appareil de compression un ventilateur double du système de M. Perrigault, ingénieur-constructeur à Rennes. Ce ventilateur a été mis très-obligeamment à ma disposition par MM. Farcot père et fils. M. Ernest Gouin en a fait de même pour la locomobile qui avait déjà fourni sa force motrice pour les expériences du Conservatoire.

On a essayé successivement des jets de $0^m.07$, $0^m.10$ et $0^m.122$ de diamètre.

La pression effective de l'air comprimé mesurée par un manomètre à eau placé sur un renflement de la conduite a varié entre les limites de $0^m.23$ et de $0^m.65$ de hauteur d'eau.

Les jets étaient installés au centre de gravité de la galerie rayonnante et tout près de son origine.

Les expériences se divisent en deux séries, suivant que les caillebotis étaient enlevés ou en place.

Huit expériences ont été faites sans caillebotis, et huit avec caillebotis.

La valeur moyenne de la constante C pour les huit premières expériences est de. . . . . . . . . . . . . . . . . . . . . . . . 3,916,678

Ce qui donne pour le coefficient K, quand les grilles sont enlevées :

$$K = 1.09.$$

La valeur moyenne de la constante C pour les huit dernières expériences est de. . . . . . . . . . . . . . . . . . . . 2,552,593

Ce qui donne pour le coefficient de résistance K, quand les grilles sont en place :

$$K = 1.30.$$

Ces deux valeurs de K sont probablement trop faibles.

La cause ne saurait être attribuée à la ventilation naturelle dont l'influence a été reconnue négligeable.

Il faut la rechercher dans les indications du manomètre à eau, installé sur un simple renflement de la conduite d'insufflation du ventilateur double, et qui pour cette raison étaient probablement trop faibles.

En effet, Messieurs, si vous voulez bien vous reporter à la formule (9)

$$u = \frac{A_0}{K} \times \frac{d}{D} \times \sqrt{\mu},$$

vous reconnaîtrez immédiatement que la valeur de la vitesse $u$ étant donnée directement par l'observation, s'il y a erreur en moins sur l'observation de la pression $\mu$, le coefficient K doit être entaché lui-même d'une erreur en moins.

Ce qui nous a confirmé, M. Tresca et moi, dans cette opinion, c'est que le rendement du ventilateur double Perrigault, calculé d'après les pressions $\mu$ observées, n'a été trouvé que de 0.40 en moyenne, tandis qu'on est fondé à croire que ce rendement est supérieur.

Quoi qu'il en soit, l'erreur sur le rendement du ventilateur n'a eu aucune influence sur l'observation du volume d'air entraîné à diverses vitesses par force de cheval-vapeur du moteur.

En effet, la locomobile qui a fourni la force motrice avait été essayée au frein au Conservatoire et pour ainsi dire tarée d'avance.

On pouvait donc déterminer directement la force développée dans chaque expérience, par l'observation de la pression absolue de la chaudière et du nombre de tours du volant, l'orifice d'admission de la vapeur dans le cylindre étant ouvert en grand.

Les résultats intéressants à citer ici sont ceux relatifs aux huit dernières expériences, parce que les conditions dans lesquelles elles ont été faites se rapprochent autant que possible de celles de l'application.

Je résume ces expériences dans le petit tableau ci-après :

| Nos des expériences. | Diamètre des jets moteurs. | Vitesse d'entraînement. $u$ | Force en chevaux développée par le moteur. F' | Volume entraîné à la vitesse $u$ par cheval-vapeur du moteur. $\frac{Eu}{F'}$ | Volume entraîné à la vitesse d'un mètre par cheval-vapeur du moteur. $\frac{Eu^2}{F'}$ | Volume entraîné à la vitesse de $1^m.00$ par kil. de charbon. $\frac{Eu^2}{n}$ |
|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
| | m. | m. | c. | mètres cubes. | mètres cubes. | mètres cubes. |
| 1 | 0.07 | 1.91 | 7.29 | 5,665 | 10,820 | 4,328 |
| 2 | 0.07 | 1.28 | 2.83 | 9,777 | 12,515 | 5,006 |
| 3 | 0.07 | 1.10 | 2.04 | 11,647 | 12,812 | 5,125 |
| 4 | 0.07 | 1.26 | 2.08 | 13,085 | 16,487 | 6,595 |
| 5 | 0.10 | 2.47 | 10.55 | 5,049 | 12,471 | 4,988 |
| 6 | 0.122 | 2.60 | 9.17 | 6,133 | 15,946 | 6,378 |
| 7 | 0.122 | 2.50 | 8.86 | 6,090 | 15,225 | 6,090 |
| 8 | 0.122 | 2.54 | 9.00 | 6,096 | 15,484 | 6,194 |
| | | Moyennes. ........ | | 7,943 | 13,970 | 5,588 |

Les chiffres des cinq premières colonnes sont extraits du rapport de M. Tresca. Ceux des deux dernières colonnes s'en déduisent.

Vous voyez, Messieurs, que la moyenne de l'entraînement par cheval-vapeur du moteur, à la vitesse de 1 mètre, est de 13,970 mètres, et que cette moyenne par kilogramme de charbon est de 5,588.

Ce résultat remarquable tient à l'emploi de jets d'air comprimé à très-basse pression.

M. Tresca, voulant se rendre compte de la répartition de l'air dans chacune des trois galeries souterraines circulaires, a fait mesurer avec un anémomètre à main la vitesse à l'entrée de ces trois galeries. Il a reconnu ainsi, comme il le fait remarquer dans son procès-verbal, que cette répartition était sensiblement proportionnelle au nombre des caillebotis. Chacun de ces orifices d'admission débite donc à peu près le même volume d'air.

Cela tient à ce que la somme des sections libres des caillebotis d'un secteur est sensiblement égale à la section de la galerie rayonnante dans laquelle s'opère le refoulement.

Tels sont en substance les résultats des expériences préalables faites sur le secteur no 3.

Leur importance ayant frappé M. le commissaire général, j'ai été invité par ce haut fonctionnaire à étudier de suite un projet pour l'application du nouveau système au Palais, en collaboration avec M. Cheysson, ingénieur des ponts et chaussées, chef du service du 6e groupe.

C'est ce projet qui a été approuvé par la Commission impériale, qui est aujourd'hui en voie d'exécution, et dont je vais maintenant avoir l'honneur de vous entretenir.

## APPLICATION AU PALAIS DU CHAMP DE MARS.

L'application dont il s'agit emploiera une force totale de 105 chevaux répartie en quatre centres de force motrice autour du Palais. Cette force sera nécessaire pour produire dans la galerie rayonnante une vitesse d'entraînement de 2 mètres par seconde[1].

La vitesse de $2^m$ par $1''$ correspond à un refoulement d'air total de 700,000 mètres cubes environ par heure.

En effet, si vous voulez bien vous reporter à la moyenne d'entraînement par force de cheval à la vitesse d'un mètre, que les expériences ont fait ressortir au chiffre de 13,970 mètres cubes, il est évident que pour la vitesse de 2 mètres, cet entraînement moyen sera réduit à la moitié de ce chiffre, soit à 6,985 mètres cubes.

Pour tenir compte de l'augmentation de résistance qu'on rencontrera probablement dans l'application, je réduis ce dernier chiffre à 6,700 mètres cubes.

Je trouve ainsi :

$$6{,}700^{mc} \times 105 = 703{,}500^{mc}.$$

La force motrice étant proportionnelle au carré de la vitesse d'entraînement, il suffirait de 25 à 26 chevaux pour produire la vitesse de 1 mètre dans les galeries rayonnantes, et pour obtenir un refoulement d'air de 350,000 mètres cubes par heure.

Cette dernière combinaison donnerait au moins 10 mètres cubes d'air par visiteur et par heure, et assurerait convenablement l'expulsion de la proportion d'air vicié.

Mais ce n'est pas là le seul but qu'on doit se proposer dans la ventilation d'un édifice, qui en raison de sa forme et de son mode de construction, sera particulièrement exposé à la réverbération des rayons solaires. La chaleur absorbée par la toiture tendra à échauffer la masse d'air intérieure, en se propageant de haut en bas.

C'est pour combattre, autant que possible, cette cause d'élévation de la température intérieure que le projet de ventilation a été basé sur une vitesse d'entraînement de 2 mètres dans les galeries rayonnantes, et par conséquent sur l'emploi d'une force motrice d'au moins 100 chevaux-vapeur.

Le premier centre de force motrice que l'on rencontre en partant du

1. Au moment où le projet de ventilation a été mis sur le tapis, il n'était pas très-facile d'improviser une force motrice de 105 chevaux, répartie aussi également que possible autour du Palais.

Mais M. Cheysson, qui a la force motrice du Palais dans ses attributions, a résolu ce problème très-habilement et très-heureusement

pont d'Iéna et en tournant à gauche, se compose d'une locomobile de 15 chevaux actionnant deux ventilateurs doubles semblables à celui qui a servi aux expériences préalables.

Cette installation se fait dans le parc, à côté de la chaudière de MM. Chevalier et Duvergier, de Lyon.

Les ventilateurs sont fournis par M. Perrigault lui-même; et l'installation est faite par MM. Farcot père et fils, propriétaires-constructeurs de la locomobile.

Ce premier centre alimentera deux jets d'air comprimé et ventilera les secteurs nos 3 et 4 du Palais.

Le deuxième centre de force motrice est situé dans l'intérieur du bâtiment annexe de la chaudière belge. Il consiste dans un exhausteur à gaz à 3 cylindres de $0^{m}.80$ de diamètre et de $0^{m}.70$ de course, actionnés par un cylindre unique à vapeur. Cet appareil de compression est installé par M. Gargan, constructeur de machines à Paris. Il est du même modèle que ceux qui fonctionnent à l'usine à gaz de la Villette, à la grande satisfaction de la Compagnie parisienne, et qui sont dus à ce constructeur.

La force motrice, estimée à 25 chevaux, sera prise directement sur la chaudière belge.

Ce deuxième centre alimentera 4 jets et ventilera les secteurs nos 5, 6, 7 et 8 du Palais.

Le troisième centre est situé dans l'intérieur même de la grande galerie des machines, section des États de l'Allemagne du Sud. L'appareil de compression se compose de 2 grands ventilateurs doubles Perrigault, qui empruntent une force motrice de 25 chevaux sur l'arbre de couche du Palais.

Les choses sont disposées de façon à ce que l'air aspiré et comprimé par les ventilateurs sera emprunté à la galerie d'aérage et non point à l'atmosphère de la galerie des machines.

C'est encore MM. Farcot père et fils qui sont chargés de cette installation. Toutefois, les ventilateurs sont construits par M. Perrigault lui-même.

Le troisième centre alimentera 4 jets moteurs et est destiné à la ventilation des secteurs nos 9, 10, 11 et 12.

Enfin le quatrième centre, dont la force est de 40 chevaux-vapeur, s'installe sur un terrain situé dans le Parc, vis-à-vis de la section anglaise.

MM. Gauthier et Philippon, constructeurs à Paris, sont chargés de cette installation qui se composera d'une machine demi-fixe, du système de M. Philippon, et de deux cylindres à air ou machines soufflantes dont le diamètre est de $1^{m}.20$ et la course de $0^{m}.80$.

Ce quatrième et dernier centre alimentera 6 jets moteurs et ventilera les secteurs nos 13, 14, 15, 16, 1 et 2.

Telles sont les dispositions prises pour la production de l'air comprimé.

Le volume qui sera ainsi comprimé par heure par ces quatre centres de force motrice développant toute leur puissance, sera de 30 à 35,000 mètres cubes, sous des pressions effectives variant entre $0^m.30$ et $0^m.80$ de hauteur d'eau.

Pour conduire l'air comprimé aux orifices des 16 jets moteurs, on doit poser des conduites en tôle bitumée du système Chameroy.

Ces conduites forment 4 réseaux distincts correspondants aux 4 centres de force motrice.

La conduite maîtresse de chaque réseau a naturellement son point de départ au récipient de chaque centre et est dirigée d'abord sur le puits d'aérage le plus voisin. Elle s'engage ensuite dans la galerie d'aérage où elle se bifurque au besoin, pour aboutir aux jets moteurs.

Le diamètre de ces conduites varie entre $0^m.60$ et $0^m.30$.

Vous comprenez, Messieurs, qu'en raison de la faible pression de l'air comprimé, il était nécessaire de le faire circuler à petite vitesse dans de grands diamètres pour diminuer autant que possible les pertes de charges.

Ces diamètres ont été calculés de façon à ce que la moyenne de la perte de charge sur le jet moteur ne dépasse pas 2 à 3 centimètres d'eau.

Pour pouvoir modifier à volonté la section de l'orifice de sortie de l'air comprimé, et par suite la vitesse d'entraînement dans les galeries rayonnantes, au lieu de se servir d'ajutages mobiles, comme dans les expériences du Conservatoire et du Champ de Mars, on installera un appareil injecteur à disque démasquant 4 secteurs disposés symétriquement par rapport à l'axe de l'appareil.

Cet appareil injecteur, qui est construit par la maison Gouin et qui a été spécialement étudié par M. Fouquet, ingénieur attaché à cette maison, porte un cadran sur lequel une aiguille indique la section démasquée dont le maximum peut aller jusqu'à 130 centimètres carrés.

Tels sont les différents appareils qui concourent à la ventilation générale du Palais.

Je vous ai déjà fait remarquer, Messieurs, que l'aspiration devait se faire par 16 puits d'aérage de 3 mètres de diamètre, disposés à peu près symétriquement autour du Palais sur la bissectrice de l'angle formé par deux galeries rayonnantes contiguës.

Il résulte de cette disposition que l'air fourni par un puits se partagera en deux parties sensiblement égales entre les deux galeries rayonnantes situées à droite et à gauche.

La galerie d'aérage a sensiblement la même section que la galerie rayonnante, soit 6 mètres carrés. La vitesse de l'air n'y sera donc que moitié de celle de la galerie rayonnante, soit environ 1 mètre par 1″.

Mais pour que l'aspiration puisse se faire dans des conditions normales, il est nécessaire que la section de la voûte du puits qui met celui-ci en

communication avec la galerie d'aérage, soit au moins de 6 mètres carrés, puisque cette voûte doit débiter à peu près la même quantité d'air que la galerie rayonnante.

Or, en fait, la section de ces voûtes des puits est loin d'atteindre 6 mètres carrés. Elles sont toutes plus ou moins surbaissées et encombrées de façon à ce que leur section se trouve réduite à $4^{mc}.50$ environ.

C'est pour parer à ce grave inconvénient qu'on établit en ce moment un certain nombre de grilles de ventilation sur le promenoir de la marquise extérieure et communiquant directement avec les galeries d'aérage.

Ces rentrées d'air supplémentaire étaient indispensables pour assurer ce qu'on peut appeler le service de l'aspiration de l'air extérieur.

Quant à l'expulsion de l'air intérieur vicié ou échauffé, elle n'est assurée que par l'action de la ventilation naturelle des galeries d'exposition et par la sur-pression produite par le refoulement de l'air nouveau.

Cette évacuation doit se faire, sans résistance sensible, par les ouvertures des persiennes ménagées à cet effet. C'est du reste l'opinion émise par M. Tresca dans son rapport.

Toutefois, il est à craindre que l'interposition de hautes cloisons entre les grilles d'arrivée et les persiennes d'évacuation ne soient une cause de résistance sur laquelle on ne comptait pas.

Il est à craindre, en tout cas, par suite de l'installation de ces hautes cloisons, que l'air nouveau fourni par la ventilation ne se répartisse pas également sur toute la surface du Palais, comme cela était prévu, et qu'on ne remarque des espaces ouverts où la ventilation sera très-active à côté d'espaces fermés où l'air nouveau ne pénétrera pas.

Un dernier mot sur le prix de revient de la ventilation du Palais.

Le volume d'air fourni sera, en comptant par unité de mille mètres cubes :

| | |
|---|---|
| Par heure. . . . . . . . . . . . . . . . . . . . . . . | 700 unités. |
| Par jour à raison de 7 heures 1/2. . . . . . . . . . . | 5,250 — |
| Pour toute la durée de l'Exposition évaluée à 150 jours seulement, 5,250 × 150 = . . . . . . . . . . . | 787,500 — |

Or, la dépense totale relative à l'application du système ne dépassera pas 78,750 fr.

Le prix de revient de 1,000 mètres cubes d'air nouveau envoyé dans le Palais sera donc, tout compris, *d'environ* 0 fr. 10.

Nous avons vu plus haut que ce prix était de 0 fr. 16 pour la ventilation du pavillon des femmes de l'hôpital de Lariboisière.

Me voici, Messieurs, arrivé au terme de la communication que je m'étais proposé de faire à votre honorable Société.

Il me reste à vous remercier pour la bienveillante attention que vous avez bien voulu m'accorder.

Si, à votre prochaine séance, vous voulez bien m'accorder encore quelques instants, je vous présenterai quelques considérations sur l'application du nouveau système à la ventilation des hôpitaux, des théâtres, des navires, ainsi qu'à la soufflerie des forges.

M. Lehaître se propose de vous exposer lui-même le programme général de l'application aux mines.

Mais, indépendamment de ces applications, le nouveau système est susceptible d'être appliqué à la métallurgie, ainsi que vous allez le voir tout à l'heure par l'expérience que prépare M. Wiessnegg.

Voici un appareil simple de petite dimension, dans lequel l'air comprimé va déterminer un courant rapide. Il suffit pour obtenir ce résultat de calculer convenablement le rapport des deux diamètres $d$ et D et la pression $\mu$ de l'air moteur.

Embranchons sur la conduite de cet appareil et dans l'intérieur même du cône d'expansion une tubulure inclinée, comme celle que vous voyez ici.

Faisons maintenant communiquer cette tubulure avec un récipient contenant un gaz combustible qui sera soit de l'hydrogène pur, soit de l'hydrogène carboné, soit de l'oxyde de carbone, soit même tout simplement du gaz d'éclairage.

Il est facile de se rendre compte de l'effet qui va se produire.

L'air comprimé moteur, en se détendant dans la conduite, produit une dépression en arrière du cercle qui forme la base du cône d'expansion.

Or, c'est précisément dans cette région que se trouve placée la tubulure du gaz combustible.

Celui-ci sera donc aspiré avec plus ou moins de force, et dans une proportion qu'il est facile de régler au moyen d'un robinet.

L'air comprimé, l'air atmosphérique entraîné et le gaz combustible aspiré vont se mélanger *d'une manière intime* dans leur trajet par l'appareil, condition indispensable pour le succès de l'opération qui se prépare et qui se trouve réalisée de la manière la plus simple par la seule force motrice du jet d'air comprimé.

J'ajouterai de suite que ce jet moteur étant fourni par un récipient qu'il est extrêmement facile d'entretenir à pression constante, ainsi que vous avez pu en juger vous-même par les expériences précédentes, le courant général sortant par l'orifice de l'appareil aura une *stabilité* qu'il serait impossible d'obtenir avec tout autre système de soufflerie.

Il ne reste plus maintenant qu'à mettre le feu à ce courant pour obtenir une flamme dont la puissance calorifique dépasse celle de tous les chalumeaux connus jusqu'à ce jour.

En effet, cet appareil réalise admirablement, et de la manière la plus simple, les deux conditions essentielles des chalumeaux : le *mélange in-*

*time* des gaz avant leur combustion et la *stabilité absolue* du courant enflammé.

Vous savez, Messieurs, que les choses en apparence les plus simples, sont souvent celles qui exercent le plus le génie inventif de l'homme, et vous reconnaîtrez certainement que l'addition de cette tubulure, qui transforme immédiatement notre appareil de ventilation et de soufflerie en un chalumeau d'une puissance extraordinaire, fait le plus grand honneur à son auteur, M. Wiessnegg, jeune constructeur d'appareils de précision.

M. Wiessnegg va faire fonctionner l'appareil devant vous avec du gaz d'éclairage. Il se propose de fondre, en quelques minutes, des rivets dans un creuset, et de les transformer en un culot de fer doux semblable à celui-ci, qui a été obtenu en ma présence, par le même procédé.

## DEUXIÈME PARTIE.

J'ai eu l'honneur d'exposer devant vous, à votre dernière séance, les principales formules de la théorie de la ventilation par l'air comprimé.

Craignant d'abuser de votre attention, je m'étais appliqué à concentrer autant que possible la partie théorique, évitant d'aborder des considérations qui n'étaient pas absolument indispensables, soit pour définir théo riquement le fonctionnement du nouveau système, soit pour établir des bases de comparaison avec les systèmes actuellement en usage.

Une observation de votre honorable président m'a semblé contenir un reproche amical de ma brièveté sur ce point.

Je crois dès lors convenable de compléter mon premier exposé par deux considérations qui se déduisent de la théorie et qui, présentant certain caractère pratique, auront probablement quelque intérêt pour vous.

Je veux parler d'abord de la proportion d'air atmosphérique entraîné par le jet comprimé moteur, proportion qui va prendre des valeurs différentes suivant que l'on comparera les volumes ou les poids.

Les éléments de cette double comparaison sont implicitement contenus dans la formule fondamentale :

$$mV = MU. \tag{1}$$

Vous savez, messieurs, que cette formule est relative à l'*appareil simple*.

S'il s'agit d'un appareil quelconque dont le coefficient de résistance est K,

on aura : $$u = \frac{U}{K} \text{ et } U = K \times u;$$

d'un autre côté on peut écrire :

$$M = \frac{\delta \times \omega}{g} U = K \times \frac{\delta \times \omega}{g} \times u.$$

Donc $$MU = K^2 \times \frac{\delta \times \omega}{g} \times u^2 = K^2 M' u$$

en désignant par M′ la masse $\frac{\delta \times \omega}{g} u$ qui est refoulée par 1″ dans l'appareil quelconque que l'on considère.

J'écrirai donc d'une manière générale :

$$mV = K^2 M'u. \qquad (2)$$

La masse M' est la masse totale refoulée par 1″, elle comprend donc la masse $m$ de l'air comprimé moteur.

Pour établir la proportion des masses, c'est-à-dire des poids, il suffit d'écrire :

$$\frac{M'}{m} = \frac{V}{K^2 u}; \qquad (3)$$

et

$$\frac{M' - m}{m} = \frac{V}{K^2 u} - 1. \qquad (4)$$

L'équation (3) donne le nombre de kilogrammes d'air refoulé à la vitesse $u$, par kilogramme d'air comprimé.

L'équation (4) donne le poids de l'air aspiré dans les mêmes conditions.

Si l'on opère dans l'appareil simple, à la vitesse d'entraînement de 1 mètre, la formule (3) se réduit à :

$$\frac{M'}{m} = V. \qquad (5)$$

Dans ces conditions la proportion des poids est égale à la vitesse de l'air comprimé.

Or vous savez, Messieurs, que la vitesse de l'air comprimé a une limite supérieure, qui n'est autre que celle du coefficient $Ao = 404^{m}.4$.

En effet, cette vitesse est donnée par la formule :

$$V = \sqrt{\frac{2gp}{\rho}}. \qquad (6)$$

$p$ étant la pression effective et $\rho$ le poids du mètre cube de l'air comprimé.

Remplaçons $p$ par $\pi \times \mu$ et $\rho$ par $(\mu + 1)\delta$, conformément à la loi de Mariotte, nous aurons alors :

$$V = \sqrt{\frac{2g\pi}{\delta} \times \frac{\mu}{\mu + 1}}, = Ao\sqrt{\frac{\mu}{\mu + 1}}. \qquad (7)$$

Si dans cette dernière équation (7), nous faisons $\mu = \infty$, nous aurons pour la limite supérieure de la vitesse V :

$$Vo = Ao = 404^{m}.4. \qquad (8)$$

C'est la vitesse de l'air comprimé à une pression quelconque s'échappant dans le vide.

Ainsi, 1 kilogramme d'air comprimé à une pression quelconque, ne

peut entraîner plus de $404^k$ d'air atmosphérique, à la vitesse de 1 mètre par 1''.

Si, maintenant, nous considérons la proposition des volumes entraînés, nous devrons poser, en désignant ces volumes par Q et par $q$ :

$$\frac{Q}{q} = (\mu + 1)\frac{M'}{m}; \qquad (9)$$

Ce qui donnera :

1° pour le refoulement :

$$\frac{Q}{q} = \frac{\mu + 1}{K^2} \times \frac{V}{u}; \qquad (10)$$

2° pour l'aspiration :

$$\frac{Q-q}{q} = \frac{\mu + 1}{K^2} \times \frac{V}{u} - 1. \qquad (11)$$

On voit ainsi que la proportion des volumes de l'air atmosphérique entraîné, et de l'air comprimé moteur, mesuré sous pression, va toujours en augmentant avec la pression.

Dans l'expérience faite devant vous, à la dernière séance, avec l'ajutage de $0^m.0003$ et la pression $\mu = 1$, nous avions $K^2 = 1$, et la vitesse d'entraînement $u$ était environ $0^m.60$.

La proportion des volumes était donc :

$$\frac{Q}{q} = \frac{2 \times 286}{0.60} = 953;$$

c'est-à-dire qu'un litre d'air comprimé, mesuré sous pression, entraînait, dans les conditions de l'expérience, 953 litres d'air atmosphérique.

Au moyen de ces nouvelles formules et de celle donnée dans la dernière séance, on pourra calculer d'avance le volume d'air entraîné à la vitesse $u$, dans un appareil de ventilation quelconque :

1° Par force de cheval de jet comprimé;

2° Par force de cheval du moteur, et par kil. de charbon consommé;

3° Par kil. d'air comprimé ;

4° Par mètre cube d'air comprimé, mesuré sous pression.

Toutes les circonstances du phénomène de l'entraînement de l'air par l'air, se trouvent ainsi déterminées par le calcul.

Je vais aborder maintenant la seconde considération qui est relative au refroidissement de l'air entraîné.

Que se passe-t-il, au point de vue de la température, dans un jet d'air comprimé qui sort d'un récipient, que je supposerai entretenu à une pression constante et à la température de l'air ambiant?

Vous savez parfaitement, Messieurs, que ce jet d'air comprimé sortant

librement dans l'atmosphère, subira un refroidissement *considérable*, et d'autant plus grand que sa pression sera plus élevée.

Avec les moyens très-limités dont nous disposons, MM. Lehaître, Jullienne et moi, nous sommes parvenus à obtenir un abaissement de 42° centigrades, avec un jet d'air comprimé entre 4 et 5 atmosphères effectives.

Sur un récipient contenant environ 50 litres d'air comprimé à ladite pression, était adapté un robinet de $0^m.025$ de diamètre.

Un thermomètre très-sensible était maintenu à la main dans la partie cylindrique du robinet comprise entre la clef et l'orifice de sortie.

L'air du récipient était à la température ambiante; on ouvrait rapidement le robinet. L'air comprimé se lançait dans l'atmosphère en faisant osciller violemment la boule du thermomètre, qui cependant ne venait pas se briser sur la paroi du robinet, parce que le jet comprimé sert ici de coussin.

On voyait immédiatement le thermomètre descendre rapidement. Un intervalle de 6″ suffit pour l'écoulement total de l'air contenu dans le récipient, sous l'influence seule de la détente, et pour faire descendre le thermomètre de 42°.

Nous avons répété plusieurs fois cette expérience; et nous avons vu le thermomètre passer en 6″ de $+22°$ à $-20°$.

La boule se couvrait de glace et de petits glaçons, ou plutôt de petits *grêlons* étaient projetés avec force.

M. Tresca, qui dispose au Conservatoire de moyens beaucoup plus puissants, m'a dit avoir obtenu des abaissements de température beaucoup plus considérables.

Ainsi voilà un fait bien constaté par l'expérience : c'est le froid produit par la détente d'un jet d'air comprimé qui s'élance dans l'atmosphère.

Si donc nous employons, pour produire un entraînement d'air atmosphérique dans une conduite, un jet d'air comprimé sortant d'un réservoir entretenu à pression et à température constantes, il est évident, *à priori*, que le froid de la détente du jet moteur se répartira dans toute la masse entraînée, et que le volume d'air ainsi refoulé sera plus ou moins rafraîchi.

Il est certainement intéressant de pouvoir constater d'avance la valeur de cet effet réfrigérant.

La théorie de l'entraînement que j'ai eu l'honneur de vous exposer, combinée avec la nouvelle théorie mécanique de la chaleur, permet d'aborder ce problème ; et je vais vous en soumettre une solution.

Pour simplifier la question, je vais considérer ce qui doit se passer dans l'appareil simple.

La force vive du jet moteur est :

$$\frac{mV^2}{2};$$

Celle du courant de ventilation est :

$$\frac{MU^2}{2}.$$

Or, en vertu de la relation fondamentale :

$$mV = MU,$$

nous avons : $$\frac{MU^2}{2} = \frac{mV}{2} \times U = \frac{mV^2}{2} \times \frac{U}{V}.$$

Donc : $$\frac{MV^2}{2} - \frac{MU^2}{2} = \frac{mV}{2}(V - U). \qquad (12)$$

Ce qui indique qu'il y a nécessairement une perte de force vive plus ou moins grande due au phénomène de l'entraînement de l'air par l'air.

D'après la théorie mécanique de la chaleur, toute force vive perdue doit être représentée par un nombre équivalent de calories communiquées aux corps en mouvement.

Posons donc l'équation :

$$\frac{mV^2}{2} - \frac{MU^2}{2} = C \times E. \qquad (13)$$

C étant le nombre de calories correspondant à la force vive perdue par le fait de l'entraînement, et E l'équivalent mécanique de la chaleur.

Les équations (12) et (13) donnent :

$$E \times C = \frac{mV}{2}(V - U). \qquad (14)$$

Nous savons qu'immédiatement à sa sortie de l'orifice, le jet comprimé éprouve, par le fait de la détente, un abaissement de température.

Soit $t$ la température de l'air comprimé dans le récipient, laquelle est, par hypothèse, égale à celle de l'air ambiant.

Soit $t_1 < t$ la température du courant rafraîchi par la détente de l'air comprimé moteur.

Soit $t'$ la température à laquelle l'air comprimé descendra par l'effet de la détente.

Cet air se réchauffera ensuite, dans la période d'entraînement, en remontant de $t'$ à $t_1$, tandis que l'air atmosphérique entraîné se refroidira en descendant de $t$ à $t_1$.

Soient enfin :

$$t_1 - t' = \theta; \text{ et } t - t_1 = \tau.$$

Je puis calculer maintenant le nombre de calories C que l'air comprimé empruntera à l'air entraîné, pour passer de la température $t'$ à la température $t_1$ du mélange.

J'aurai d'abord :

$$C = \frac{\pi d^2}{4} \times V \times \theta \times (\mu + 1)\,\delta \times \gamma. \qquad (15)$$

J'aurai également :

$$C = \frac{\pi D^2}{4} \times U \times \tau \times \delta \times \gamma. \qquad (16)$$

L'équation (15) donne le nombre de calories gagnées par l'air comprimé pour se réchauffer de $\theta$ degrés.

L'équation (16) donne le nombre de calories perdues par l'air entraîné pour se refroidir de $\tau$ degrés.

Ces deux quantités seront égales, si l'on néglige les pertes par radiation, ce qui donne d'abord :

$$\frac{\theta}{\tau} = \frac{D^2}{d^2} \times \frac{U}{(\mu+1)V} = \frac{V}{U}. \qquad (17)$$

Ainsi je constate d'abord que les différences de température $\theta$ et $\tau$ sont entre elles dans le même rapport que les vitesses V et U.

Maintenant, la combinaison des équations (14) et (15), donne :

$$\frac{mV}{2}(V - U' = E \times \frac{\pi d^2}{4} \times V \times \theta \times (\mu+1) \times \delta \times \gamma.$$

On en tire, toute réduction faite :

$$\theta = \frac{V(V-U)}{2 \times E \times g \times \gamma}. \qquad (18)$$

et par suite :

$$\tau = \frac{U(V-U)}{2 \times E \times g \times \gamma}. \qquad (19)$$

Si maintenant je fais :

$$E = 430,$$
$$g = 9.81,$$
$$\gamma = 0.237,$$

j'aurai sensiblement :

$$\theta = \frac{V(V-U)}{2.000}. \qquad (20)$$

et

$$\tau = \frac{U(V-U)}{2.000}. \qquad (21)$$

Telles sont les formules qui donnent les différences de température $\theta$ et $\tau$, par application de la théorie mécanique de la chaleur combinée avec celle de l'entraînement de l'air par l'air.

Supposons que l'entraînement ait lieu par un jet d'air comprimé, produisant une vitesse d'entraînement très-petite dans une conduite d'un diamètre très-grand, nous pourrons négliger la valeur de U et écrire :

$$\theta = \frac{V^2}{2.000};$$

et en faisant $V = Vo = 404^m.4$, limite de vitesse de l'air comprimé, nous aurons :

$$\theta_0 = \frac{(404.4)^2}{2.000} = 81°77.$$

Cette valeur de $\theta_0 = 81°\ 77$ représente le *maximum d'abaissement de température produit par la détente, à l'air libre, d'un jet d'air comprimé à haute pression.*

Il était évident *à priori*, que la vitessee de l'air comprimé ayant une limite, le froid produit par la détente d'un jet comprimé, sortant à l'air libre devait également en avoir une.

Cette limite supérieure serait d'environ 80°, d'après la théorie que je viens de vous exposer.

Quant à l'abaissement de température $\tau$, qui dans certaines applications de ventilation par l'air comprimé, peut jouer un rôle important, sa valeur croît proportionnellement et à la vitesse d'entraînement U, et à la différence V — U.

D'Alembert est le premier qui ait proclamé ce grand principe : *qu'il n'y avait pas de force perdue en mécanique.*

Les géomètres ont pensé d'abord que le principe n'était pas exempt d'exceptions, par exemple dans le cas du choc qui donne lieu à une perte de force vive.

Mais la théorie mécanique de la chaleur nous démontre aujourd'hui victorieusement que cette perte de force n'est qu'apparente, attendu qu'elle est compensée par une production de chaleur équivalente, et que la chaleur est elle-même une force.

Dans l'entraînement de l'air par l'air, il y a choc des molécules d'air entre elles, et par suite perte de force vive.

Mais cette perte de force se trouve compensée par une production de chaleur qui a pour effet de réchauffer le jet comprimé moteur; et comme la chaleur nécessaire pour produire cet effet est empruntée à l'air entraîné, la perte de force vive se trouve finalement compensée par le rafraîchissement de la masse d'air mis en mouvement.

C'est une compensation qui n'est pas à dédaigner dans un grand nombre d'applications à la ventilation.

Je crois devoir limiter ici les considérations théoriques, et je vais maintenant aborder la question des applications du nouveau système.

### 1° APPLICATION A LA MÉTALLURGIE.

Messieurs, dans votre dernière séance, vous avez été témoins d'un résultat métallurgique obtenu avec un chalumeau à l'air comprimé qui n'est autre que notre appareil ordinaire de ventilation transformé au moyen d'une addition due à M. Wiessnegg. Ce jeune et habile constructeur a obtenu la fusion du fer doux en votre présence.

Il obtient aussi facilement la fusion du platine.

Vous savez que les chalumeaux à gaz d'éclairage ont fait dans ces derniers temps de très-grands progrès. M. Schlœsing, ingénieur des manufactures de l'État, a réalisé un appareil de cette espèce, avec lequel il obtient aisément la fusion du fer doux, et qui peut remplacer avec avantage les fourneaux employés dans les laboratoires pour les températures les plus élevées. La limite de pouvoir du chalumeau Schlœsing est vers la fusion du platine, soit environ 2000°. (Voici à ce sujet le compte rendu de l'Académie des sciences, en date du 4 décembre 1865.)

Je crois devoir citer ici l'appareil de M. Schlœsing, parce qu'il a une certaine analogie avec celui à l'air comprimé.

Les deux appareils diffèrent toutefois essentiellement par le mode de soufflerie, celui de M. Schlœsing marchant avec un soufflet ordinaire qui nécessite l'emploi d'un gazomètre entretenu à une pression constante.

Pour faire produire aux chalumeaux à gaz leur maximum de puissance, pour pouvoir augmenter notablement leurs dimensions actuelles, en un mot, pour pouvoir sortir du domaine du laboratoire et aborder celui de l'industrie, il est indispensable d'avoir une soufflerie débitant des volumes d'air considérables avec une régularité pour ainsi dire mathématique.

Or, le chalumeau à l'air comprimé peut seul réaliser pratiquement ces conditions.

Rien ne s'oppose, en effet, à une augmentation de ses dimensions; et si on l'applique un jour à l'industrie métallurgique, ce n'est pas la puissance de la soufflerie qui fera défaut, ni la facilité avec laquelle on pourra faire marcher à la fois plusieurs appareils concourant au même but.

Dans une application de ce genre, l'oxyde de carbone dont la production est si facile et si économique, viendrait naturellement remplacer le gaz d'éclairage.

Il n'y aurait qu'à se préoccuper de l'emmagasinement de ce gaz combustible, sa marche étant assurée d'avance par le jet d'air comprimé moteur.

### 2° APPLICATION AUX HOPITAUX.

La plus belle application que l'on puisse faire d'un système de ventilation quelconque, c'est assurément à une salle d'hôpital.

C'est ici surtout qu'il est important que les deux termes du problème soient résolus indépendamment l'un de l'autre :

1° Évacuation de l'air vicié;

2° Refoulement d'air nouveau, aussi pur que possible, par des ouvertures disposées de manière à ne pas incommoder les malades.

La proportion de l'air nouveau introduit doit être sensiblement égale à

celle de l'air vicié expulsé, afin qu'il ne se manifeste par les portes et les fenêtres, ni rentrées ni sorties.

Si ce programme était exactement rempli, il est certain que la ventilation de la salle d'hôpital serait parfaite, le volume d'air ainsi renouvelé étant convenablement calculé par lit et par heure.

Je vais me proposer d'abord de rechercher jusqu'à quel point ces conditions se trouvent satisfaites, avec les deux systèmes de ventilation employés jusqu'à ce jour.

Je prendrai, pour exemple, le magnifique hôpital de Lariboisière où la question de ventilation a été traitée peut-être avec plus de soin qu'ailleurs.

Vous savez, Messieurs, que cet hôpital comprend six pavillons construits sur le même modèle. Trois sont affectés aux hommes, et trois aux femmes.

Les pavillons des hommes sont ventilés par insufflation, au moyen d'un ventilateur mécanique dont j'ai déjà eu occasion de parler.

Les pavillons des femmes sont ventilés par le système de l'appel direct de la chaleur.

Je parlerai d'abord des pavillons des hommes.

L'air nouveau est refoulé mécaniquement dans la salle par des poêles disposés sur la ligne centrale.

Ce mode de rentrée est très-bien compris. Il ne saurait incommoder les malades dont les lits sont adossés aux murs longitudinaux.

L'air nouveau pénétrant au centre de la salle à une hauteur d'un mètre environ au-dessus du sol, et à petite vitesse, s'épanche librement à droite et à gauche dans toutes les parties de la salle.

Pour évacuer l'air vicié, on a adopté une disposition qui met les trois salles d'un même pavillon en communication avec une cheminée en zinc de $1^m.24$ de diamètre, établie au-dessus du centre du grenier, et qui domine le faîte du pavillon.

De petites cheminées de $0^m.20$ à $0^m.25$ de côté sont pratiquées dans l'épaisseur des deux murs longitudinaux de chaque pavillon, et présentent dans chacune des trois salles, des orifices situés à diverses hauteurs et que l'on peut démasquer à volonté. Ces petites cheminées, au nombre de 54 par pavillon, débouchent toutes dans deux grandes gaînes horizontales établies dans le grenier au-dessus des murs longitudinaux. Ces deux gaînes horizontales, qui sont fermées à leurs deux extrémités, communiquent à leur tour avec la base de la cheminée de ventilation.

Cette disposition, qui ouvre ainsi un chemin à l'air vicié des salles est abandonnée à l'action de la ventilation naturelle, aidée de la force expulsive due au refoulement de l'air nouveau par les poêles.

Si chaque salle était hermétiquement fermée de toutes parts, comme un réservoir d'air, il est certain que la totalité de l'air nouveau refoulé mécaniquement, ne pourrait sortir que par la cheminée de ventilation.

Mais en pratique, et on le comprend facilement, les choses sont loin de se passer ainsi.

M. le général Morin, qui s'est beaucoup étendu sur cette importante question dans son ouvrage déjà cité, va nous apprendre comment elles se passent.

Le premier fait intéressant à constater est celui-ci :

Y a-t-il une différence entre le volume d'air extrait des salles par la cheminée de ventilation, et le volume d'air refoulé dans les salles par la ventilation mécanique?

M. Grassi a trouvé une différence en moins de près de 5.000$^{mc}$. par heure entre ces deux volumes [1]. Il en conclut que cet excédant d'air insufflé a dû passer par les joints des fenêtres et les ouvertures accidentelles des portes.

D'autres observations faites par MM. Trélat, Péligot, Leblanc et Ser ont fait ressortir un accord presque complet entre le volume d'air évacué par la cheminée de ventilation et celui introduit par les poêles.

Mais le volume d'air introduit par les poêles a toujours été trouvé inférieur à celui fourni par la ventilation et mesuré dans le grand tuyau porte-vent.

Si donc, on admet, comme cela paraît probable, qu'une partie de l'air refoulé pénètre dans la salle, en dehors des poêles, et par les joints des gaînes horizontales pratiquées dans l'épaisseur du plancher, les observations citées ci-dessus sont en concordance avec celles de M. Grassi.

La première conséquence à tirer de l'observation des faits serait donc celle-ci :

*Le volume d'air refoulé mécaniquement dans la salle est supérieur au volume extrait de cette même salle par la cheminée de ventilation.*

Ce résultat se comprend parfaitement.

L'air refoulé dans la salle tend à sortir par les ouvertures qui lui présentent le moins de résistance. Or, l'appareil d'évacuation pris dans son ensemble comporte évidemment une certaine somme de résistances due au parcours plus ou moins long et accidenté que l'air doit effectuer pour arriver à la base de la cheminée de ventilation. L'air ancien tend à sortir de préférence par un joint de fenêtre, ou par l'ouverture accidentelle d'une porte.

La sortie de l'air par la cheminée de ventilation se fait sous l'action simultanée de la ventilation naturelle et de la force expulsive due au refoulement de l'air nouveau.

M. le général Morin constate que cette dernière force ne contribue que pour 15 °/₀ sur l'effet total de l'évacuation de l'air vicié; le reste, soit 85 °/₀ devant être attribué à la ventilation naturelle [2].

1. *Etudes sur la ventilation*, 1$^{er}$ volume, page 383.

2. *Ibid.*, 1$^{er}$ volume, page 423.

Cette évacuation de l'air vicié doit donc varier beaucoup d'intensité, puisqu'elle dépend de deux causes : l'une qu'on peut regarder comme constante et qui est le ventilateur, et l'autre essentiellement variable, qui est l'action de la ventilation naturelle.

Ainsi trouvons-nous, dans l'ouvrage de M. le général Morin, que le volume d'air vicié, évacué par la cheminée de ventilation est moitié moins considérable en été qu'en hiver[1].

Cette irrégularité dans l'évacuation de l'air vicié constitue certainement un grand inconvénient au point de vue hygiénique.

Mais il en existe d'autres plus graves encore. Que se passe-t-il quand on ouvre quelques fenêtres dans l'une des trois salles d'un même pavillon, celles des deux autres salles restant fermées ?

Il est évident, *à priori*, que la majeure partie, sinon la totalité de l'air refoulé par le ventilateur mécanique sortira par les fenêtres ouvertes, et que le courant de ventilation naturelle des petites cheminées d'évacuation sera à peu près interrompu.

Cet effet a été observé en avril 1856, par MM. Trélat et Peligot. Ces observateurs ont même constaté un *retour d'air vicié, dans la salle du premier étage du pavillon n° 4, par suite du renversement du courant dans certains canaux d'évacuation, quand on ouvrait un certain nombre de fenêtres dans cette salle*[2].

L'air vicié qui revenait ainsi dans la salle où se faisaient les expériences et où quelques fenêtres étaient ouvertes, provenait des gaînes du grenier où se mélangent les produits viciés des 3 salles d'un même pavillon. Il provenait donc en définitive des 2 autres salles.

Il est inutile de vous faire remarquer, Messieurs, l'extrême gravité de semblables effets.

M. Grassi ne se la dissimule pas, car il dit à ce propos :

« Si le fait existait réellement, il faudrait renoncer au système, car il « est impossible d'éviter l'ouverture très-fréquente des portes et quel- « quefois des fenêtres[3]. »

Je bornerai ici, Messieurs, mes observations sur la ventilation des 3 pavillons des hommes de l'hôpital de Lariboisière.

Elles suffisent pour établir que cette ventilation est incomplète, par la raison que l'évacuation de l'air vicié n'est pas suffisamment assurée.

Un des termes du problème est seul résolu ; le second ne l'est pas.

Je passe maintenant à la ventilation des 3 pavillons des femmes.

Ici on a procédé d'une manière inverse. On applique la force directe de la chaleur à l'aspiration de l'air vicié des salles, et la rentrée de l'air nouveau est abandonnée à l'action de la ventilation naturelle.

1. *Etudes sur la ventilation*, 1er volume, page 123.

2. *Ibid.*, 1er volume, page 397.

3. *Ibid.*, 1er volume, page 398.

Les dispositions prises pour la sortie de l'air vicié, sont à peu près celles que j'ai décrites pour les pavillons des hommes.

Seulement, la cheminée d'évacuation est plus grande, plus élevée, et construite en briques.

Pour y produire l'appel, on a installé à sa base, considérablement élargie, des récipients d'eau chaude dont le nombre atteint 17.

L'eau chaude est employée ici non-seulement comme source de chaleur pour la ventilation, mais encore comme moyen de chauffage de toutes les salles d'un pavillon.

L'air nouveau rentre par des caniveaux qui prennent jour, soit sur les deux murs longitudinaux du pavillon, soit dans les caves.

Toutes les prises d'air nouveau se réunissent dans un caniveau central sur lequel on a installé quatre poêles par salle. C'est, en définitive, par ces poêles que l'air nouveau pénètre dans la salle.

De nombreuses expériences ont été faites dans le but de constater les résultats de cette ventilation, non-seulement par les personnes dont j'ai eu occasion de citer les noms à propos de la ventilation des pavillons des hommes, mais encore par M. le général Morin lui-même qui, dans son ouvrage, manifeste une prédilection marquée en faveur de ce système.

On a constaté d'abord que le volume d'air nouveau rentrant par les poêles, n'est que la moitié environ du volume évacué par la cheminée de ventilation sous l'influence de l'appel.

Le complément rentre donc par les portes et fenêtres.

M. le général Morin constate bien ce résultat ; mais il n'en discute pas les conséquences.

Cependant on comprend *à priori* qu'une rentrée d'air qui se produit par les portes et fenêtres, sur une aussi grande échelle, ne doit pas être sans inconvénient pour les malades. Indépendamment des courants d'air qui peuvent les incommoder, il est évident que l'air qui rentre par les portes de la salle, et qui provient des pièces voisines, des escaliers, etc., n'a pas le degré de pureté convenable, et peut même être déjà vicié.

Sans doute, quand on ouvre les fenêtres, on n'est pas exposé, comme dans les pavillons des hommes, à des retours d'air vicié, provenant des gaînes du grenier. L'aspiration devient au contraire plus énergique, ainsi que les expériences l'ont constaté.

Mais il n'en est pas moins prouvé que si de l'air vicié ne peut revenir dans la salle par les conduits d'aspiration, il peut en arriver par les portes.

Mon intention n'est pas d'aborder ici une discussion comparative des deux systèmes de ventilation appliqués concurremment à l'hôpital Lariboisière. Cette comparaison a été faite par M. le général Morin ; elle est tout à l'avantage du système de l'appel.

Je me bornerai à constater que le système de l'appel est tout aussi incomplet que celui de l'insufflation.

Il est évident que chacun des deux systèmes ne résout que la moitié du problème.

L'appel assure la sortie de l'air vicié; mais il n'assure pas la rentrée de l'air nouveau.

L'insufflation assure au contraire la rentrée de l'air nouveau ; mais elle n'assure pas l'évacuation de l'air vicié.

On est donc autorisé à dire que jusqu'à présent le problème de la ventilation des hôpitaux n'a point été résolu d'une manière complète.

C'est précisément cette solution complète de ce problème essentiellement humanitaire, que je vais maintenant avoir l'honneur de vous soumettre, en y appliquaut le système de la ventilation par l'air comprimé.

Je me propose même de traiter en même temps la question du chauffage, de telle sorte que le problème va se trouver posé de la manière suivante :

1° *Extraire d'une salle d'hôpital une proportion donnée d'air vicié par heure;*

2° *Refouler dans le même temps une proportion égale d'air nouveau;*

3° *L'air nouveau sera pur, et devra être introduit dans la salle par des ouvertures spéciales disposées de manière à ne pas incommoder les malades;*

4° *Pendant la saison d'hiver, l'air nouveau devra être introduit à une température calculée de manière à maintenir dans la salle le nombre de degrés réglementaire et servir ainsi de moyen de chauffage.*

En ce qui concerne d'abord l'évacuation de l'air vicié, je ne vois rien de mieux à proposer, comme installation, que ce qui existe à l'hôpital Lariboisière.

Les conduits d'évacuation pratiqués dans les murs longitudinaux entre les lits des malades, et aspirant l'air vicié à différentes hauteurs, sont fort appréciés par les médecins.

Il est démontré d'ailleurs, par les expériences des pavillons de Lariboisière ventilés par appel, que des retours d'air vicié ne sont pas à craindre dans ces conduits, si l'aspiration de la cheminée centrale de ventilation établie au-dessus de chaque pavillon est assurée.

Avec le nouveau système, il suffira, pour assurer l'évacuation de l'air vicié de tout un pavillon, d'installer un jet d'air comprimé à la base et dans l'axe de la cheminée centrale.

Le diamètre de ce jet sera réglé, suivant les besoins, et suivant l'action de la ventilation naturelle au moyen d'un injecteur à cône ou à disque.

Pour que le jet d'air comprimé puisse produire son effet dans la cheminée, il est nécessaire que celle-ci ait en hauteur environ six fois le diamètre. Dans le cas où l'on voudrait réduire cette hauteur, on pourrait installer, au lieu d'un jet unique, plusieurs jets moteurs disposés symétriquement par rapport à l'axe de la cheminée.

Cette dernière disposition était indiquée dans un projet remis, il y a

environ un an, à M. le directeur de l'Assistance publique, pour un essai de ventilation par l'air comprimé sur le pavillon des hommes n° 2, de l'hôpital Lariboisière.

Il n'y a point à se préoccuper ici de la question du transport d'une certaine quantité d'air comprimé au sommet de chaque pavillon. On sait d'avance que l'air comprimé se transporte de lui-même, et sans perte de charge sensible, à des distances considérables, dans des conduites dont les diamètres sont convenablement calculés.

La première partie du problème n'offre donc aucune difficulté.

J'aborde maintenant la question de la rentrée de l'air nouveau, et pour fixer les idées, je supposerai qu'il s'agit d'un hôpital divisé en pavillons semblables à ceux de Lariboisière.

Ces pavillons, établis sur caves, présentent un rez-de-chaussée et deux étages. Chaque étage comprend une salle principale de trente-deux lits.

Dans chacune de ces salles sont installés quatre poêles à air sur la ligne centrale.

Je conserve la disposition de ces quatre poêles qui me paraît excellente pour la rentrée de l'air nouveau et sa répartition dans la salle.

Mais aux gaînes de refoulement des pavillons des hommes et aux caniveaux d'aspiration des pavillons des femmes, je propose de substituer une disposition beaucoup plus simple et que je vais esquisser en quelques mots.

Sur les quatre lignes verticales passant par les axes des quatre poêles d'une même salle, j'établis une colonne creuse ou gaîne verticale dont la base inférieure pénètre jusque dans les caves du pavillon, et dont la partie supérieure viendra se terminer à la base du poêle de la salle du 2e étage.

La section de cette colonne ira en diminuant avec sa hauteur, de façon à ce que la partie inférieure, destinée à l'alimentation de trois poêles, soit précisément le triple de la partie supérieure qui n'aura à conduire que le volume débité par un seul poêle.

J'installe à la base de chacune de ces quatre colonnes un jet d'air comprimé qui refoulera dans les trois salles l'air nouveau pris dans les caves.

Il va sans dire que les caves étant elle-mêmes en communication directe, par des soupiraux verticaux, avec les cours et jardins qui entourent chaque pavillon, l'air nouveau, ainsi introduit, aura tout le degré de pureté désirable.

Cette disposition est à la fois simple et économique. Elle offre une certaine analogie avec celle de la grande cheminée centrale de l'hôpital de Glascow[1].

Reste maintenant la question de chauffage pendant l'hiver.

1. *Etudes sur la ventilation*, 1er volume, page 30.

Elle ne me paraît présenter aucune difficulté.

Les colonnes et les poêles qui fourniront en été de l'air frais refoulé par l'air comprimé, peuvent parfaitement fournir en hiver de l'air chaud ou plutôt de l'air tiède refoulé par le même procédé.

Pour obtenir ce résultat, il suffira d'installer dans les caves de chaque pavillon un ou plusieurs calorifères, et d'y ménager des chambres de mélange semblables à celles qui existent au Conservatoire des Arts et Métiers.

Pendant la saison d'hiver, l'air nouveau passera par la chambre de mélange.

Une telle disposition est évidemment facile à réaliser avec une manœuvre simple de portes et de registres.

Telles sont, en substance, les dispositions qu'on pourrait adopter pour la ventilation complète et le chauffage à l'air tiède d'un pavillon d'hôpital.

Permettez-moi maintenant, Messieurs, de vous soumettre un calcul approximatif de la force motrice qui serait nécessaire pour ventiler un hôpital dans ces conditions.

Supposons qu'il s'agisse d'un hôpital de l'importance de celui de Lariboisière, c'est-à-dire comportant 6 pavillons à 3 salles contenant 32 malades chacune. Ce sera en tout environ 600 malades.

Supposons en outre qu'on se propose de donner 100 mètres cubes par lit et par heure, proportion supérieure à celle admise généralement, et surtout à celle réalisée dans la pratique.

Il s'agira donc d'évacuer par heure 60,000 mètres cubes d'air plus ou moins vicié provenant des salles et d'y refouler dans le même temps un volume égal d'air nouveau.

Je ne tiendrai pas compte dans mon calcul de l'influence de la ventilation naturelle.

Je calculerai d'abord le diamètre de la cheminée d'évacuation de chaque pavillon, de manière à ce que l'air vicié en soit expulsé avec une vitesse de $2^{m}.00$ qui me paraît nécessaire pour que la ventilation ait une certaine stabilité.

Cette cheminée devant évacuer 10,000 mètres cubes par heure à la vitesse de $2^{m}.00$, son diamètre sera de $1^{m}.35$, et sa hauteur de $8^{m}.00$ environ.

Pour calculer maintenant le diamètre de la partie inférieure d'une colonne de refoulement, j'adopterai $1^{m}.00$ seulement, comme vitesse de rentrée de l'air nouveau par les poêles.

Chaque colonne devant fournir 2,500 mètres d'air nouveau par heure à la vitesse de $1^{m}.00$, le diamètre de la partie inférieure dans laquelle fonctionnera le jet moteur sera de $0^{m}.95$, correspondant à une section de $0^{mq}.71$.

La section de la colonne dans la traversée de la salle du rez-de-chaussée sera de $0^{mq}.47$.

Dans la traversée de la salle du $1^{er}$ étage la section sera réduite à $0^{mq}.24$.

L'ouverture libre de chaque poêle sera également de $0^{mq}.24$.

Quelle sera maintenant la force motrice nécessaire pour mettre l'air en mouvement dans ces appareils ?

Elle dépendra évidemment du degré de pression de l'air moteur.

Or, rien ne s'oppose à ce qu'on emploie dans l'application dont il s'agit de l'air comprimé à basse pression, comme au palais de l'Exposition universelle de 1867.

L'exagération des diamètres des conduites d'air comprimé pourrait seule faire obstacle à ce projet ; mais nous verrons plus loin que cette exagération n'est pas à craindre.

Je supposerai donc que l'air moteur sera à la pression moyenne de $0^{m}.40$ de hauteur d'eau.

Les résistances que l'air vicié éprouvera dans son passage par les conduites et gaînes d'évacuation, ne seront guère plus grandes que celles qu'on a constatées dans les galeries souterraines du Champ de Mars, surtout si on augmente un peu la section des petits conduits pratiqués dans l'épaisseur des murs longitudinaux.

Quant à celles que l'air nouveau éprouvera dans son passage par les colonnes de refoulement, elles seront évidemment moindres.

On peut donc admettre que, dans l'application projetée, les résistances seraient comparables à celles admises pour l'application au palais du Champs de Mars.

Le calcul de la force motrice peut donc être établi sur les mêmes bases.

Or, dans l'application du Champ de Mars, on a calculé sur une moyenne d'entraînement de 6,700 mètres cubes à la vitesse de $2^{m}.00$.

En partant de cette base, on trouvera que le nombre de chevaux nécessaire pour l'extraction de $60,000^{mc}$ d'air vicié par heure, sera de :

$$\frac{60,000}{6,700} = \ldots\ldots \qquad 8^{c}.95$$

Toutefois, pour tenir compte du volume de l'air comprimé qui n'est pas compris dans la masse aspirée, et qui entre dans la masse refoulée pour $\frac{1}{20}$ environ, il convient de porter l'évaluation de cette première partie de la force motrice à...... $9^{c}.40$

Quant à la force motrice nécessaire pour produire le refoulement, à la vitesse de $1^{m}$, de $60,000^{mc}$ d'air nouveau, y compris le volume de l'air comprimé moteur, on doit la calculer sur le pied de $2 \times 6,700 = 13,400^{mc}$ par force de cheval.

Elle sera donc :

$$\frac{60,000}{13,400} = \ldots\ldots \qquad 4^{c}.50$$

La force motrice totale pour la ventilation complète d'un hôpital de 600 lits, à raison de $100^{mc}$ par heure et par lit, serait donc :

$9^c.40 + 4^c.50 = \ldots\ldots$ $13^c.90$

Nombre rond : ...... $14^c.00$

C'est celle d'une locomobile ordinaire.

Quant au volume d'air comprimé, il sera au maximum :

1° $\frac{60,000}{20} = 3,000^{mc}$ pour l'aspiration ;

2° $\frac{60,000}{40} = 1,500^{mc}$ pour le refoulement.

En tout : $4,500^{mc}$ par heure.

Or, ce volume total devant se partager en deux parties égales pour être dirigé vers les pavillons, supposés disposés comme à Lariboisière, il suffira de donner à chaque conduite de départ un diamètre de $0^m.45$ à $0^m.50$, pour réduire les pertes de charge à des hauteurs d'eau insignifiantes.

Tel est, Messieurs, le projet d'application à un grand hôpital que je soumets à votre discussion éclairée.

Si vous reconnaissez que je ne me suis pas trompé dans mes appréciations, vous reconnaîtrez également, je l'espère, que les systèmes de ventilation employés jusqu'à ce jour seraient impuissants pour produire un tel effet, soit avec la force motrice de 14 chevaux, soit avec le combustible qui la représente.

Avant de quitter ce sujet si important de la ventilation des hôpitaux, veuillez me permettre de vous soumettre une dernière remarque.

Vous savez, Messieurs, que l'opinion publique s'est préoccupée, à tort ou à raison, dans ces derniers temps, alors que le choléra régnait dans Paris, de l'influence que pouvait exercer sur les environs l'air vicié sortant des cheminées de ventilation.

L'administration de l'Assistance publique a même, à cette époque, employé des moyens pour désinfecter cet air vicié avant son expulsion dans l'atmosphère.

J'aurai l'honneur de faire remarquer à ce sujet, que le système de ventilation par l'air comprimé permet de mettre en œuvre un moyen de désinfection aussi simple qu'efficace.

Il suffit, en effet, d'adapter à la base de la cheminée de ventilation une tubulure analogue à celle du *chalumeau à air comprimé.*

Cette tubulure donnera immédiatement le moyen d'appeler une proportion déterminée d'air saturé d'un principe gazeux désinfectant, tel que le chlore par exemple.

Le mélange intime qui s'opérerait dans le trajet de la cheminée favoriserait singulièrement la désinfection de l'air vicié.

### 3° APPLICATION AUX THÉATRES.

Que se passe-t-il aujourd'hui, dans nos salles de théâtre, au point de vue du renouvellement de l'air?

Le premier effet que chacun de nous a pu constater par lui-même, et qui n'est malheureusement que trop connu, c'est la rentrée de l'air nouveau par les portes.

Si de l'air nouveau rentre ainsi dans la salle, avec des vitesses assez grandes pour incommoder les spectateurs, c'est que l'air de la salle est lui-même aspiré vers l'extérieur par d'autres ouvertures et avec une certaine énergie.

On a constaté en effet, que dans les anciennes salles de théâtre, où rien n'a été prévu pour la ventilation, des quantités relativement considérables d'air étaient extraites par la seule action du lustre.

Dans une expérience faite le 25 février 1863, au théâtre de l'Opéra actuel, le volume d'air évacué par heure a atteint le chiffre moyen de 28,800 mètres cubes[1].

Cet air sort par une ouverture dont la section totale est de $4^{mq}.35$ et qui est pratiquée dans le plafond autour de la suspension du lustre.

Le 12 mars 1863, pendant un bal de nuit de la mi-carême, ce volume s'est élevé jusqu'à 33,000 mètres cubes.

En avril 1863, des expériences analogues ont constaté une évacuation d'air de 11,900 mètres cubes par heure au Théâtre-Italien.

Le lustre d'un théâtre est donc un véritable appareil de ventilation par appel, et même un appareil assez puissant.

La rentrée de l'air nouveau est nécessairement proportionnée à la sortie de l'air vicié et échauffé.

Il va sans dire que dans les anciennes salles, la totalité de l'air nouveau rentre nécessairement par les portes, quand le rideau est baissé ; et principalement par la scène, quand le rideau est levé.

Tels sont, en résumé, les effets d'aération qui se produisent dans une ancienne salle de spectacle, c'est-à-dire dans la presque totalité de nos théâtres.

Cette aération est extrêmement gênante pour les spectateurs. Aussi la température atteint-elle souvent des proportions sénégaliennes.

On a cherché à parer à ces graves inconvénients dans la construction des trois nouveaux théâtres, Lyrique, du Châtelet et de la Gaîté.

Vous connaissez sans doute, messieurs, les installations spéciales de ces nouvelles salles. Je vous demanderai cependant la permission de les rappeler ici d'une manière sommaire, avant d'en discuter les effets.

1. *Études sur la ventilation*, 2e volume, page 290.

On a d'abord substitué au lustre un système d'éclairage placé au-dessus de la salle. La lumière passe ainsi à travers un plafond lumineux.

Cette innovation peut être un progrès au point de vue de l'éclairage; mais considérée au point de vue de l'appel de l'air vicié et échauffé, elle doit occasionner un supplément de résistances.

En effet, l'air vicié ne peut plus sortir librement par les rosaces et ouvertures du plafond, comme cela a lieu dans les salles éclairées par des lustres, attendu que le plafond lumineux est complétement fermé.

Cet air est dirigé vers la coupole qui contient l'appareil d'éclairage, par une série de gaînes verticales qui communiquent avec l'atmosphère de la salle, aux divers étages, par des grilles ouvertes dans les plafonds des loges ou des salons qui y sont annexés.

Toutefois la couche inférieure d'air vicié provenant du parterre, de l'orchestre et des baignoires est appelée dans deux cheminées de ventilation spéciales par une première série d'orifices disposés sous les siéges de l'orchestre et du parterre, et une seconde série d'orifices ouverts dans le plancher inférieur des baignoires.

Les deux cheminées dont il s'agit constituent deux appareils supplémentaires de ventilation par appel, qui reçoivent les tuyaux de fumée des calorifères et qui sont munis d'ailleurs de foyers à leur base.

Telles sont les installations exécutées au Théâtre-Lyrique, pour l'évacuation de l'air vicié.

Ce système n'est pas exempt d'une certaine complication qui nécessite des soins particuliers pour en assurer le fonctionnement normal.

Il faut d'abord ne pas négliger d'allumer, en été surtout, les foyers des deux cheminées d'appel supplémentaire qui consomment 300 kilog. de charbon par soirée, précaution qui, paraît-il, est souvent négligée.

Il faut ensuite que tout le système des gaînes de communication entre la salle et la coupole d'éclairage d'une part, et d'autre part entre la salle et la base des deux cheminées de ventilation, soit entretenu en bon état, et que les registres dont sont munis les appareils soient manœuvrés avec intelligence, de manière à répartir aussi également que possible l'évacuation de l'air vicié.

Il faut enfin que la coupole qui renferme l'appareil d'éclairage ne présente d'autres ouvertures que celles des gaînes aspirant l'air vicié de la salle.

Sans cette précaution, on comprend que de l'air autre que celui de la salle serait appelé dans cette coupole. Alors le volume d'air total qui passe par la lanterne qui surmonte le toit de l'édifice, ne représenterait plus le volume réellement évacué de la salle.

Je passe maintenant aux installations relatives à la rentrée de l'air nouveau.

Ce que je vais dire se rapporte au Théâtre-Lyrique.

Pour que les rentrées d'air nouveau ne puissent incommoder les spec-

tateurs, on a pratiqué sur tout le pourtour des balustrades des loges et balcons, à tous les étages et dans la partie inférieure de ces balustrades, des ouvertures par lesquelles l'air nouveau est introduit.

Ces ouvertures communiquent avec une capacité ménagée sous le plancher des loges et balcons qui présente ainsi un double fond. Cette capacité communique, à son tour, avec le soubassement du théâtre. Enfin le soubassement est mis lui-même en communication par une grande galerie avec un puits d'aérage établi dans le square de la tour Saint-Jacques.

Tel est le chemin ouvert à l'air extérieur et qui lui permet de pénétrer dans la salle.

Le principe de cette heureuse disposition qui met les spectateurs parfaitement à l'abri des rentrées de l'air extérieur est dû à Darcet.

Dans l'application qui en a été faite au Théâtre-Lyrique, on a eu soin d'établir deux calorifères dans le soubassement, et pour ainsi dire sur le chemin de l'air nouveau.

Cette installation complétée par des chambres de mélange permet de chauffer la salle par les mêmes canaux et orifices qui servent à sa ventilation.

Telles sont, en résumé, les installations faites au Théâtre-Lyrique, en vue de sa ventilation et de son chauffage.

M. le général Morin, qui en sa qualité de rapporteur d'une commission instituée *ad hoc* par M. le Préfet de la Seine, a pris une grande part à ces installations, va nous apprendre comment fonctionne ce système.

Quelques jours après l'ouverture du théâtre, le 9 décembre 1862, on a constaté une évacuation d'air total par la lanterne de 60,051 mètres cubes et une rentrée d'air par la galerie de la tour Saint-Jacques de . . . . . . . . . . . . . . . . . . . . . . 30,850 mètres cubes.

C'est un effet de ventilation tout à fait semblable à celui qui se produit à l'hôpital de Lariboisière, pavillons des femmes, en ce sens que le volume d'air nouveau introduit n'est que la moitié environ du volume évacué. Le complément devait donc nécessairement rentrer dans la salle par les portes ou par la scène; d'où l'on est en droit de conclure que l'un des termes du problème n'est pas résolu.

Mais il est important de remarquer de suite que l'expérience ci-dessus a été faite en hiver, par une température extérieure de + 8°, et alors que les calorifères étaient allumés.

Or, il est évident que l'action de ces calorifères a dû contribuer notablement à l'aspiration de l'air du puits d'aérage.

Ces calorifères, en effet, constituent un second appareil de ventilation par appel intercalé sur le chemin que l'air extérieur parcourt entre le puits d'aérage et la salle.

On peut donc pressentir d'avance que les 30,850 mètres cubes d'air rentrant, constatés le 9 décembre 1862, sont un maximum qui n'est pas atteint en été.

Du reste l'ouvrage tant de fois cité de M. le général Morin va nous renseigner à ce sujet.

L'honorable général a consacré une note spéciale C, aux expériences qui ont été entreprises, en mai 1863, sous sa propre direction, et en vertu d'un arrêté M. le Préfet de la Seine.

Le but de ces expériences était d'avoir une appréciation des effets que l'on peut réellement obtenir des appareils établis, en les faisant fonctionner d'une manière convenable.

M. le général Morin se plaint vivement, dans cette note, de l'état d'abandon dans lequel il a trouvé les appareils, après un fonctionnement de quelques mois seulement.

Il constate d'abord que par suite de négligences qu'il attribue à la direction du théâtre, le volume d'air extrait de la salle était réduit à 23,500$^{mc}$ par heure, au commencement de mai, volume fixé par le cahier des charges à 51,000$^{mc}$, et qui atteignait le chiffre de 60,000$^{mc}$ le 9 décembre précédent.

Quant à la rentrée de l'air nouveau, par les ouvertures ménagées à cet effet, elle avait pour ainsi dire cessé de fonctionner, et le remplacement de l'air vicié ne se faisait plus que par la scène, par les couloirs et par d'autres ouvertures plus ou moins irrégulières, ce qui donnait lieu à des courants d'air fort gênants.

Après avoir fait remettre les choses en état, M. le général Morin a fait, les 23, 24, 25, 26 et 30 mai, cinq expériences dont il a consigné les résultats dans un tableau, d'où j'extrais les données suivantes :

| DATES. | TEMPÉRATURE extérieure. | Volume d'air nouveau venant du square par heure. | Volume d'air vicié évacué par heure. | Consommation de charbon par soirée. | |
|---|---|---|---|---|---|
| | | | | Calorifères. | Cheminées d'appel de l'orchestre. |
| | degrés. | m. cb. | m. cb. | k. | k. |
| 23 mai 1865.. | 14.25 | 15,439 | 53,631 | 100 | 75 |
| 24 — .... | 13.25 | 18,433 | 56,675 | » | 125 |
| 25 — .... | 11.25 | 17,223 | 53,157 | » | 200 |
| 26 — .... | 13.25 | 14,623 | 53,718 | » | 300 |
| 30 — .... | 21.00 | 10,587 | 61,718 | » | 300 |
| Moyennes. | ........... | 15.261 | 55.780 | » | » |

Il résulte de ce tableau que les ouvertures ménagées pour la rentrée de l'air nouveau n'ont pas fourni en moyenne *le tiers* du volume d'air évacué. Plus des deux tiers de ce volume rentraient donc par les portes ou par la scène.

Remarquons en outre, Messieurs, que le 30 mai, la température extérieure s'étant élevée à 21°, soit 7° de plus que le 26 mai, le volume d'air

nouveau venant du square n'a atteint qu'un *sixième* environ du volume évacué.

Cette indication donne une idée des effets de la ventilation d'été.

M. le général Morin, en la signalant lui-même, fait remarquer qu'il avait prévu cette diminution de la rentrée de l'air nouveau extérieur, au fur et à mesure de l'élévation de la température de cet air, et que pour remédier à cet inconvénient, il avait proposé, pour la saison d'été, l'ouverture de prises d'air plus directes.

Quoi qu'il en soit, nous voici suffisamment renseignés sur les effets de ventilation du Théâtre-Lyrique; et je vais les résumer en quelques mots, ainsi qu'il suit :

1° Pendant la saison d'hiver, le volume d'air nouveau extérieur qui rentre dans la salle, par les ouvertures ménagées à cet effet, est d'environ *moitié* du volume d'air vicié évacué par l'aspiration de l'appareil d'éclairage et des deux cheminées d'appel supplémentaires.

2° Au printemps, cette proportion tombe au-dessous du *tiers*.

3° Dans la saison d'été elle diminue jusqu'au *sixième*.

Il est donc bien établi que le problème de la ventilation n'a point été résolu d'une manière complète dans les installations de nos nouveaux théâtres.

Il ne le sera réellement que le jour où l'on parviendra à égaliser le volume évacué et le volume rentrant par les ouvertures ménagées à cet effet, de façon à annuler complétement les rentrées d'air par les portes, qui sont le principal inconvénient de nos salles de spectacle.

Il me reste maintenant à vous soumettre, Messieurs, une solution complète du problème, solution qui vous frappera par sa simplicité.

Je vais prendre pour exemple le Théâtre-Lyrique, puisque nous sommes maintenant familiarisés avec ses dispositions.

En ce qui concerne l'évacuation de l'air vicié, je ne changerais rien aux installations actuelles qui peuvent fournir une évacuation de 60,000$^{mc}$ d'air par heure.

Je ne ferais intervenir l'entraînement de l'air comprimé que dans le cas où cette évacuation serait reconnue insuffisante.

Je ne changerais rien non plus aux dispositions prises pour la rentrée de l'air nouveau venant du puits d'aérage du square de la tour Saint-Jacques.

L'application du nouveau système se bornerait ici à l'installation d'un jet comprimé moteur dans l'axe de la galerie souterraine existante entre le puits d'aérage et le soubassement du théâtre.

Il est évident que cet air, qui aujourd'hui n'est entraîné que par l'action de la ventilation naturelle, et dans des proportions notoirement insuffisantes, sera ainsi forcé de pénétrer dans la salle, et cela dans une proportion que l'on pourra déterminer d'avance.

On sera donc certain de pouvoir refouler ainsi un volume égal et

même un peu supérieur au volume d'air vicié évacué, *ce qui annulera complètement les rentrées par les portes.*

Vous me trouverez peut-être, Messieurs, trop affirmatif sur ce dernier point, qui est ici en définitive le nœud de la question.

Mais permettez-moi de vous citer une expérience que nous avons faite plusieurs fois, MM. Lehaître, Julienne et moi, dans une petite salle située dans le jardin du n° 76 de la rue du Cherche-Midi, expérience qui peut se répéter à volonté et que nous mettons à votre disposition. Cette expérience va vous démontrer immédiatement : que lorsqu'on extrait d'une salle un certain volume d'air et qu'on y refoule artificiellement un volume sensiblement égal, aucune rentrée d'air ne peut se produire dans ladite salle, par des orifices autres que ceux par lesquels l'air nouveau est introduit.

La petite salle dont je parle contient environ 13$^{mc}$ d'air.

Un jet d'air comprimé fonctionnant dans une petite cheminée en zinc de 0$^{m}$.12 de diamètre, y produit l'extraction.

La salle est construite en planches. Tous les joints des portes et fenêtres ont été calfeutrés avec beaucoup de soin.

Quand l'appareil d'extraction fonctionne, les portes et fenêtres étant parfaitement closes, l'air extérieur rentre par deux ouvertures circulaires de 0$^{m}$.12 de diamètre chacune.

A l'une de ces ouvertures, le n° I, on adapte une conduite en fer-blanc de 0$^{m}$.12 de diamètre, et d'une dizaine de mètres de longueur dans l'axe de laquelle on peut faire fonctionner à volonté un second jet d'air comprimé.

Cette installation élémentaire est une reproduction en petit de celle qui existe au Théâtre-Lyrique. Le premier jet d'air comprimé remplace l'appel de l'appareil d'éclairage.

La conduite en fer-blanc représente la prise d'air du square, et son orifice dans la salle les ouvertures ménagées pour la rentrée de l'air extérieur.

Enfin le deuxième orifice circulaire représente une porte de loge ouverte.

Quand le premier jet fonctionne seul, on constate deux rentrées d'air : 1° par la conduite et l'orifice n° 1; 2° par l'orifice n° 2.

La première est moins considérable que la seconde, en raison des résistances que l'air éprouve dans son trajet par la conduite.

Quand on fait fonctionner simultanément les deux jets, de manière à ce que les deux courants sortant et rentrant aient sensiblement la même vitesse, la rentrée par l'orifice n° 2 est *annulée instantanément, et cela au point que la lumière d'une bougie n'y subit aucune déviation.*

C'est le résultat très-net de cette expérience, laquelle a frappé toutes les personnes qui en ont été témoins, qui m'autorise à affirmer ici, que les choses ne doivent pas se passer autrement dans une grande salle de

théâtre, où l'on sera parvenu à équilibrer l'aspiration et le refoulement.

Si l'aspiration domine le refoulement, on aura toujours plus ou moins l'inconvénient des rentrées d'air par les portes des loges.

Si, au contraire, le refoulement domine l'aspiration, il ne pourra s'établir par ces ouvertures qu'un courant dirigé du dedans au dehors, lequel sera sans inconvénient pour les spectateurs, ainsi que le démontre la sortie de l'air vicié des amphithéâtres du Conservatoire, qui n'incommode nullement les auditeurs.

Dans le problème de la ventilation d'une salle de théâtre, le terme dont l'importance domine est incontestablement la rentrée de l'air nouveau. L'extraction de l'air vicié ne vient qu'en seconde ligne.

Il importe, en effet, avant tout, que la salle soit largement approvisionnée d'air nouveau, frais en été et tiède en hiver.

Il n'est pas absolument nécessaire que la totalité de l'air nouveau introduit dans la salle, par les ouvertures ménagées à cet effet, passe par les gaînes d'évacuation.

L'excès de cet air peut être expulsé sans inconvénient, soit par les ouvertures des portes, soit par la scène.

J'ajouterai que le volume d'air refoulé, doit être calculé, non-seulement sur la base d'un renouvellement suffisant au point de vue hygiénique, mais encore en vue de combattre l'élévation de la température qui tend à se produire dans la salle.

Pour résoudre le problème ainsi posé, par application au Théâtre-Lyrique, il suffirait, comme je l'ai déjà dit, d'installer un jet d'air comprimé moteur dans la galerie souterraine qui met en communication le puits d'aérage et le soubassement du théâtre.

Quelle serait la force motrice nécessaire pour entretenir un jet moteur capable de refouler dans la salle 65,000 mètres cubes par heure?

Le calcul est bien facile.

La section de cette galerie est d'environ $9^{m.q}.00$, ce qui correspond à un diamètre de $3^{m}.40$.

La vitesse d'entraînement, dans cette galerie, correspondant au volume de 65,000 mètres cubes est, à peu de chose près, de $2^{m}.00$.

Si les résistances dues au refoulement étaient ici les mêmes qu'au palais du Champ de Mars, on pourrait calculer sur un entraînement de 6,700 mètres cubes par force de cheval du moteur, en admettant de l'air comprimé à la pression moyenne de $0^{m}.40$ d'eau.

Mais il est probable que les résistances seraient un peu plus grandes, et, pour cette raison, je réduirai le chiffre précédent à 6,500 mètres cubes.

La force du moteur serait donc d'environ 10 chevaux, pour produire un refoulement d'air de 65,000 mètres cubes, *indépendamment de la ventilation naturelle.*

En tenant compte de cette action qui peut atteindre 30,000 mètres cubes en hiver, et qui descend en été à 10,000 mètres cubes et probablement au-dessous, on peut admettre que la force moyenne à développer par le moteur serait réduite à 8 chevaux environ.

En calculant sur 10 chevaux, on voit que la dépense de charbon par heure ne serait que de 25 kilogrammes, soit de 150 kilogrammes par soirée, en tenant compte de l'allumage.

Ce n'est que la moitié de la consommation des deux cheminées de ventilation supplémentaire du théâtre, qui appellent l'air vicié du parterre, de l'orchestre et des baignoires, dans une proportion qui ne dépasse pas 20,000 mètres cubes par heure[1].

Ce simple rapprochement vous démontre que l'application du nouveau système au Théâtre-Lyrique, choisi comme exemple, serait en tout cas économique.

### 4° APPLICATION AUX NAVIRES.

Je m'aperçois aujourd'hui, Messieurs, que j'ai agi dans la dernière séance avec une certaine légèreté, en m'engageant à vous soumettre aujourd'hui des considérations relatives à l'application du nouveau système aux navires.

Je vous prierai de m'excuser si je ne remplis pas cette partie du programme.

Je ne possède pas encore une somme de renseignements suffisante pour aborder cette importante question, et pour la traiter devant vous d'une manière convenable.

Si les renseignements nous manquent, la conviction ne nous fait pas défaut.

Nous croyons fermement, mes collaborateurs et moi, que le nouveau système, convenablement appliqué, est susceptible de rendre les plus grands services à bord des bâtiments de la marine militaire et commerciale, et surtout des navires à vapeur.

Ces derniers possèdent une force motrice considérable, sur laquelle un emprunt de 2 pour cent environ, au profit de la ventilation complète du navire, passerait pour ainsi dire inaperçue.

L'air comprimé, transportant lui-même sa propre force, serait amené sur un point quelconque de l'intérieur du bâtiment pour y provoquer le renouvellement de l'air.

L'air nouveau serait pris au-dessus du pont et rentrerait par des manches à vent, sous la pression de l'air comprimé.

L'air vicié, expulsé par la même force, serait dirigé vers la cheminée du navire laquelle jouerait ici le rôle de cheminée générale d'évacuation.

1. *Etudes sur la ventilation.* 2e volume, page 355.

Je crois devoir me borner, quant à présent, à ces indications générales, me réservant, si vous voulez bien m'y autoriser, de vous soumettre plus tard une communication spéciale sur cette question.

### 5° APPLICATION A LA SOUFFLERIE DES FORGES.

Il ne s'agit pas ici, Messieurs, de remplacer les machines soufflantes des hauts-fourneaux. Notre prétention est beaucoup plus modeste. Elle se borne à la soufflerie des forges ordinaires.

Je vais prendre comme exemple les forges d'une usine importante que je supposerai alimentées, comme cela a lieu généralement, par le fonctionnement d'un ventilateur simple à force centrifuge.

Pour pouvoir établir une comparaison, au point de vue de la force motrice, avec cet appareil de soufflerie et celui que je me propose d'y substituer, je supposerai que la moyenne de la pression dans les carneaux porte-vent est de $0^m.10$ de hauteur d'eau, que le nombre des tuyères est de 50, et que le diamètre moyen de ces tuyères est de $0^m.07$.

Je ne tiendrai compte, dans mon calcul comparatif, ni de la perte de charge que l'air comprimé par le ventilateur doit éprouver, dans son trajet par les carneaux, entre la bouche du ventilateur et chaque tuyère, ni des fuites de ces carneaux.

Ceci posé, je vais d'abord calculer la force en chevaux-vapeur de la somme des 50 jets alimentés par le ventilateur à la pression de $0^m.10$ d'eau, qui correspond à une vitesse de sortie de 40 mètre par 1″.

La force motrice d'un jet d'air comprimé, d'un centimètre de diamètre, à la pression $\mu$ correspondante à la vitesse de sortie V, est donnée par la formule :

$$f = 0.0108 \times \mu V. \qquad (23)$$

Si dans cette formule nous faisons :

$$\mu = 0.01 \text{ ; et } V = 40 \text{ ;}$$

nous aurons :

$$f = 0^c.00432.$$

La force totale de 50 jets de $0^m.07$ de diamètre sera donc :

$$F = 0.00432 \times 49 \times 50 = 10^c.58.$$

En admettant maintenant 22 °/₀ pour le rendement du ventilateur, on trouve pour la force motrice développée par le moteur :

$$F' = \frac{10.58}{0.22} = 48^c.10.$$

Ainsi donc, une force motrice de 50 chevaux environ, serait nécessaire

pour alimenter, au moyen d'un ou plusieurs ventilateurs mécaniques, une soufflerie de 50 tuyères de $0^m.07$ de diamètre, à la vitesse de $40^m.00$.

Voici maintenant l'installation que nécessiterait l'application de l'air comprimé à cette soufflerie.

1° Le moteur serait employé à comprimer de l'air à la pression moyenne de $0^m.90$ de hauteur d'eau, soit à la pression effective : $\mu = 0^a.09$ ;

2° Cet air serait d'abord emmagasiné dans un récipient de quelques mètres de capacité, afin de pouvoir régulariser la pression indépendamment du nombre des tuyères fonctionnant à la fois;

3° L'air comprimé serait conduit du récipient aux tuyères par une canalisation en fonte ou en tuyaux Chameroy, dont les diamètres seraient calculés de manière à réduire autant que possible les pertes de charge;

4° Des branchements seraient pratiqués au droit de chaque forge et alimenteraient des jets moteurs installés dans l'axe et à la base de chaque tuyère portant pavillon et présentant un diamètre intérieur de $0^m.07$;

5° L'orifice du jet serait obturé et réglé à volonté par un appareil injecteur à cône semblable à celui-ci.

Il résulte de cette installation, que l'ouvrier pourra faire varier à volonté l'énergie du courant de la tuyère, et que ce courant présentera une stabilité pour ainsi dire absolue, si la pression est maintenue constante dans le récipient.

Avec le système actuel, la vitesse maximum du courant de la tuyère est limitée par la pression des carneaux porte-vent, et l'ouvrier ne peut faire varier que le volume de ce courant, et non pas sa vitesse.

La nouvelle soufflerie présenterait donc des avantages pratiques incontestables sur les souffleries actuelles.

Je vais maintenant calculer la force motrice nécessaire pour entretenir les 50 jets moteurs fonctionnant simultanément, à la pression moyenne de $0^m.90$ d'eau, et produisant dans chaque tuyère un courant de $40^m.00$ de vitesse.

La tuyère étant un appareil simple, et la vitesse d'entraînement ne dépassant pas $40^m.00$, je puis appliquer ici, pour le calcul du diamètre du jet, la formule :

$$U = 404.4 \times \frac{d}{D} \times \sqrt{\mu}.$$

Si dans cette formule je fais :

$$U = 40^m.00\,;$$

$$D = 0^m.07\,;$$

$$\text{et } \mu = 0^a.09\,;$$

j'obtiendrai, toutes réductions faites :

$$d = 0^{m}.023.$$

Ainsi il faudra ouvrir l'injecteur à cône, de manière à ce que l'orifice de sortie de l'air moteur soit équivalent à un cercle de $0^{m}.023$ de diamètre, pour obtenir dans la tuyère un courant de $40^{m}.00$ de vitesse par 1″.

La force motrice en chevaux-vapeur des 50 jets, à la pression de $0^{a}.09$, correspondante à la vitesse de 116 mètres, sera donnée par l'expression :

$$F = 0.0108 \times 0.09 \times 116 \times 50 \times 5.29 = 29^{c}.82.$$

Nous pouvons admettre maintenant 60 °/₀ pour le rendement d'un jeu de pompes de compression, dans le genre des exhausteurs à gaz.

Ce qui nous donnera, pour la force développée par le moteur :

$$F' = \frac{29^{c}.82}{0.60} = 49^{c}.70.$$

Soit en nombre rond, 50 chevaux.

On voit donc que la force motrice serait à peu près la même dans les deux installations de soufflerie que je viens de comparer entre elles.

Mais les avantages pratiques de la soufflerie à air comprimé ressortent d'eux-mêmes. Je crois inutile d'insister davantage sur cette question.

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J'ai terminé, Messieurs, et je crains d'avoir abusé de votre temps.

Permettez-moi de vous remercier de nouveau pour votre bienveillante attention.

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## COMMUNICATION de M. Lehaître sur la Ventilation des mines au moyen de l'air comprimé.

M. de Mondésir, dans la dernière séance de la société, vous a exposé la théorie du système de ventilation par l'air comprimé et du principe d'entraînement des fluides gazeux, il vous a expliqué le moyen qui sera employé pour la ventilation du gigantesque bâtiment destiné à l'Exposition universelle de 1867, et il vient d'exposer celui qu'on pourrait employer avec avantage, pour les salles de spectacles, les hôpitaux, les navires et pour les salles et appartements où la réunion d'un grand nombre de personnes exige un renouvellement de l'air, soit pour rendre à peu près constante la température, soit pour fournir aux spectateurs, malades, etc., un volume d'air ou d'oxygène suffisant pour que la respiration puisse se faire dans de bonnes conditions hygiéniques.

Pour continuer l'exposé général de la ventilation par l'air comprimé, je vais avoir l'honneur de vous parler d'une manière succincte des moyens de ventiler les mines.

Les mines ont surtout besoin d'une ventilation très-active, car en outre de l'air vicié produit par la respiration des ouvriers, il y a encore un grand nombre de causes qui permettent le dégagement de miasmes et de gaz délétères, ce qui rend l'air des mines, non-seulement irrespirable en très-peu de temps, mais encore dangereux, à cause des inflammations qui peuvent résulter de quelques-uns de ces gaz.

Toutes les mines ne sont pas dans les mêmes conditions : les gaz qui se répandent dans les galeries, provenant en grande partie des minerais extraits, sont de différentes natures, mais on peut dire qu'ils sont tous délétères, soit par eux-mêmes, soit par l'altération qu'ils font subir à l'air ambiant en diminuant dans le volume de cet air la quantité d'oxygène nécessaire aux organes respiratoires. Il faudrait donc, pour expliquer complétement le système de la ventilation des mines, examiner toutes les extractions que l'on fait dans les travaux souterrains et indiquer pour chaque cas particulier un moyen spécial de ventilation.

Ce travail entraînerait dans de trop longs développements, mais comme le principe même de la ventilation serait le même, nous pensons qu'il convient de se borner à l'exposition du système pour les mines de charbon et principalement pour celles dites *à grisou*, c'est-à-dire pour celles qui dégagent des gaz combustibles et qui sont sujettes, par suite, à des détonations causant de si grands malheurs aux ouvriers employés dans ces mines et de si grandes pertes aux propriétaires.

DES CAUSES DE L'ALTÉRATION DE L'AIR DANS LES GALERIES DES MINES.

Dans ces mines, les causes qui altèrent très-promptement l'air respirable et qui changent la composition de cet air sont nombreuses, mais les principales sont :

1° La respiration et la transpiration des ouvriers, qui versent dans l'air des galeries de l'acide carbonique, de l'azote et de la vapeur d'eau.

2° La combustion des lampes, dont les ouvriers sont obligés de se servir, ce qui augmente le volume d'acide carbonique, de l'azote et de la vapeur d'eau.

3° La respiration des animaux qui servent au transport des matériaux extraits, nouveau dégagement d'acide carbonique, d'azote et de vapeur d'eau.

4° La décomposition et la fermentation des matières fécales et animales, qui produit des miasmes dangereux et des gaz délétères comme le sulfite-hydrique.

5° La combustion lente de la houille, du bois servant aux blindages, et la décomposition des pyrites, donnent lieu également à un développement d'acide carbonique et produisent un dégagement de gaz combustibles, dont les principaux sont l'hydrogène, l'hydrogène proto-carboné, l'hydrogène bicarboné et l'oxide de carbone.

Quelques mines, mais heureusement en très-petit nombre, dégagent en outre naturellement de l'acide sulfureux et du sulfide-hydrique.

La chaleur naturelle du sol, celle produite par le séjour des hommes et des animaux et aussi la nécessité d'avoir un grand nombre de lampes allumées, augmente la température de l'air des galeries des mines. On conçoit donc, bien facilement, que toutes ces causes réunies doivent rendre l'air des galeries irrespirable en très-peu de temps; aussi il est nécessaire et indispensable pour une bonne exploitation, de renouveler souvent cet air, afin que les ouvriers puissent se trouver dans des conditions hygiéniques qui leur permettent de travailler, tout en se trouvant dans un milieu sujet à de si grandes variations de composition.

Il est facile de calculer la quantité d'air qu'il faudrait fournir dans les galeries pour renouveler l'air vicié par la respiration des ouvriers, par les lampes et par la respiration des animaux employés dans les mines; mais il n'en est point de même pour la combustion lente des minerais, des pyrites et des bois, car cette combustion est plus ou moins active suivant que la température de la mine est plus ou moins élevée, qu'il y a dans les galeries une plus ou moins grande quantité de vapeur d'eau, qui facilite la décomposition, et aussi parce que le dégagement des gaz combustibles se produit en plus ou moins grande quantité, suivant la nature

de la houille de la mine et même, sur certains points seulement de cette mine, suivant le degré de décomposition du charbon.

On voit, par ce que l'on vient de dire, combien il est difficile de calculer le volume de l'air à envoyer dans les galeries des mines, pour que la ventilation soit complète, pour que l'air de ces galeries soit toujours respirable.

Tous les gaz qui se forment dans les galeries des mines et qui altèrent la composition de l'air, ont des densités très-différentes. Quelques-uns l'acide carbonique, l'acide sulfureux, l'acide sulfhydrique dont les densités par rapport à l'air sont de 1,53, 2,24 et 1,19 restent dans la partie inférieure des galeries, tandis que le gaz hydrogène protocarboné, hydrogène, hydrogène bicarboné et oxyde de carbone, dont les densités sont 0,60, 0,97, 0,07 et 0,96 se placent dans les parties supérieures des galeries.

Tous les gaz de la première catégorie, c'est-à-dire tous ceux qui ont une densité plus grande que celle de l'air et qui ont, par suite, une tendance à rester dans les parties inférieures des galeries, sont tous délétères par eux-mêmes; ils agissent sur l'économie animale comme des poisons, et leur action toxique est très-considérable, si l'air en renferme de 2 à 4 p. 100. Dans un milieu où l'air renferme de 6 à 10 p. 100 d'acide carbonique les lumières s'éteignent et la respiration de l'homme est impossible[1].

Tous les gaz plus lourds que l'air, et qui se déposent par suite dans les parties inférieures des galeries, ne sont point combustibles, à l'exception, toutefois, de l'acide sulfhydrique qui est détonant. Mais heureusement il se trouve toujours en très-petites quantités dans les mines, il est très-délétère par lui-même, son odeur si désagréable le fait facilement reconnaître : on peut facilement, par suite, prendre des précautions spéciales pour éviter ses effets, sur les points où l'on apercevrait son dégagement.

Les gaz plus légers que l'air sont tous combustibles, et par suite plus ou moins détonants, c'est-à-dire qu'ils ont la propriété de s'enflammer au contact d'une flamme, d'une étincelle électrique, en produisant une détonation semblable à celle de la poudre. Cette inflammation des gaz combustibles ne peut cependant se faire si l'air n'est point mélangé dans une certaine proportion avec ces gaz, c'est-à-dire si l'oxygène de cet air ne vient point former leur combustion : aussi l'on remarque qu'une flamme s'éteint presque subitement, lorsqu'elle est plongée dans l'un des gaz combustibles.

Les gaz qui se forment dans les mines de charbon et qui sont, comme

1. Pour que la respiration des ouvriers puisse s'opérer sans difficulté et sans danger pour leur santé, il faut que l'air ne renferme point au delà de 0,25 à 0,30 p. 100 d'acide carbonique, c'est-à-dire de $2\frac{1}{2}$ à 3 pour 1000.

nous l'avons dit l'hydrogène, l'hydrogène protocarboné, l'hydrogène bicarboné et l'oxyde de carbone, exigent donc pour produire des détonations, leur mélange avec une certaine quantité d'air, pouvant fournir l'oxygène indispensable pour la formation des combinaisons nouvelles de gaz.

Les gaz combustibles qui se trouvent dans les mines sont donc tous détonants lorsqu'ils sont en communication avec l'air, mais il y a des limites supérieures et inférieures de mélange, où la détonation ne peut s'effectuer, soit que l'air ne renferme point une assez grande quantité de gaz combustible, soit que l'oxygène de cet air et par suite son volume, ne soit point en assez grande quantité pour produire la combustion.

D'après les expériences si remarquables de Davy, Dumas, Bischoff, et autres chimistes, rapportées dans un ouvrage de M. Hamal sur l'aération des mines, les limites extrêmes d'inflammation des gaz combustibles des mines sont, pour le gaz le plus inflammable, de 1/6 de gaz pour la limite supérieure et 1/14 pour la limite inférieure.

Les produits de la combustion des gaz des mines sont différents pour chacun de ces gaz.

Pour l'hydrogène bicarboné, la combinaison produite est de la vapeur d'eau, de l'acide carbonique et de l'azote.

Pour l'hydrogène protocarboné, les produits de la déflagration sont les mêmes, mais dans des proportions différentes.

Pour l'hydrogène, la combinaison produite est de la vapeur d'eau et de l'azote.

Enfin pour l'oxyde de carbone, les produits formés sont acide carbonique et azote.

On remarquera que les gaz produits par la combustion sont tous délétères et ont des actions très-toxiques sur l'économie animale.

Lors de l'inflammation d'un de ces gaz ou de plusieurs gaz combustibles mêlés ensemble, la chaleur développée est immense, elle s'élève entre 2000 et 2800 degrés, et elle produit une dilatation de 8 à 10 fois le volume primitif.

On conçoit donc combien doit être terrible une détonation dans les mines, puisque si les ouvriers n'ont point été atteints par la flamme, c'est-à-dire s'ils n'ont point péri immédiatement par l'excès de chaleur développée, ils se trouvent lancés à de grandes distances dans les galeries par le courant immense produit par l'augmentation du volume de l'air, puis ensuite ils sont tirés avec force, en sens contraire, par le contre-courant qui se forme, lorsque l'air reprend sa température normale, sur le point où l'explosion s'est faite.

Ces détonations exposent donc la vie des malheureux mineurs, mais elles ont encore beaucoup d'autres inconvénients, en détruisant une partie des blindages par le choc qu'elles produisent, et en occasionnant des éboulements dans les galeries, de sorte que les ouvriers qui ont pu échap-

per aux atteintes des flammes et du choc de l'air, se trouvent isolés quelquefois entre deux éboulements et ils sont souvent condamnés à périr par asphyxie, malgré l'activité qu'on déploie pour les sortir de leur tombeau.

Ces éboulements et surtout les ébranlements produits par les détonations, deviennent pour les propriétaires de mines des causes d'énormes dépenses, parce qu'ils sont obligés de faire faire des travaux confortatifs pour redonner aux galeries la solidité convenable.

Tous les gaz combustibles dégagés dans les mines, à l'exception cependant de l'oxyde de carbone, qui est heureusement peu abondant, ne sont point délétères par eux-mêmes, c'est-à-dire qu'ils ne produisent point les effets toxiques des gaz plus lourds que l'air; ils rendent l'air moins respirable, parce qu'ils diminuent la quantité d'oxygène, et l'effet de leur mélange dans l'air est à peu près celui produit par une diminution de pression au fur et à mesure que l'on s'élève dans l'atmosphère. Cette propriété des gaz combustibles les rend plus dangereux parce que les ouvriers ne s'aperçoivent point de suite de leur présence dans les galeries, et s'ils n'ont point le soin d'examiner la flamme de leur lampe de sûreté, qui s'allonge au fur et à mesure que l'air se sature de ces gaz, ils peuvent se trouver enveloppés, sans s'en douter, de mélanges détonants qui peuvent faire explosion, par une étincelle sortant des lampes, ou même par le choc d'un outil d'acier sur un corps dur et siliceux.

Tous les gaz combustibles, ainsi que nous venons de le dire, sont plus légers que l'air, ils se logent naturellement dans les parties supérieures des galeries, dans les joints des blindages, entre les chapeaux des fermes et principalement dans les poches ou anfractuosités qui existent dans les plafonds supérieurs des galeries, il est donc souvent difficile de les chasser de ces réduits; ils se trouvent aussi dans les joints et fissures des bancs de houille, avec de très-fortes pressions et lorsque les mineurs taillent et abattent des masses de houille, ils se dégagent dans les chantiers en assez grande abondance, surtout dans les houilles pulvérulentes et dans celles qui ont de nombreuses fissures.

Tous les gaz qui se forment dans les mines, comme tous les gaz en général, qu'ils soient plus lourds ou moins lourds que l'air, jouissent de la propriété connue sous le nom de *diffusion*, c'est-à-dire qu'ils ont une tendance à se mélanger avec l'air ambiant, lorsque cet air est agité, mais on comprend que la diffusion est d'autant plus active que la densité des gaz se rapproche davantage de celle de l'air. Lorsque le mélange est opéré, il est souvent fort difficile de séparer les corps gazeux, et ce n'est qu'avec un calme parfait et un temps assez long que la séparation peut s'opérer.

Cette propriété de la diffusion des gaz, tout à fait analogue à celle des mélanges des liquides, est d'un grand avantage pour obtenir, dans les galeries des mines, le mélange des gaz avec l'air de ces galeries, parce

qu'en renouvelant cet air on peut enlever aussi tous les gaz dangereux, mais pour quelques gaz, comme l'hydrogène et l'hydrogène protocarboné, dont les densités sont si inférieures à celles de l'air, la diffusion est peu considérable et l'on a remarqué, dans un grand nombre de mines à *grisou*, que le dégagement du gaz hydrogène protocarboné (entrant, on le sait, pour la plus grande partie dans le grisou), n'opère point sa diffusion, ou l'opère avec beaucoup de difficulté, si le courant général de l'air de la galerie est contraire à celui que tend à suivre le gaz au moment de son dégagement.

## CALCUL APPROXIMATIF DU VOLUME D'AIR A INTRODUIRE DANS UNE GALERIE DE MINE ET DANS UN CHANTIER DE 100 MINEURS.

Maintenant que nous avons, d'une manière succincte, expliqué les diverses causes qui rendent l'air des galeries des mines de houille irrespirable pour les ouvriers, dangereux par les explosions occasionnées par les gaz produits, nous allons chercher quel est le volume d'air qu'il serait nécessaire de fournir aux galeries et comment on devrait procéder pour obtenir la diffusion des gaz et accélérer leur sortie de la mine. Ce calcul, comme nous l'avons déjà dit, ne peut être que très-approximatif, parce qu'il n'est point le même pour toutes les mines; aussi nous croyons nécessaire, pour obtenir une aération convenable, d'augmenter dans une énorme proportion la quantité d'air à fournir, de manière à acquérir la certitude que cette masse d'air soit toujours de beaucoup supérieure à celle indispensable pour obtenir des mélanges non délétères.

Nous prendrons pour exemple une mine occupant, dans l'un de ses étages, un nombre de 100 ouvriers.

Ces 100 ouvriers, pour leur propre respiration, exigeront un volume d'air de 12 mètres chacun (ce chiffre a été reconnu indispensable pour des ouvriers, parce qu'ils ont besoin d'une plus grande quantité d'air pendant le travail qu'à l'état de repos). Le volume de l'air à renouveler, pour la respiration des ouvriers, est donc par heure de. . $1{,}200^{\text{mc}}$

La quantité d'air vicié par les lampes est, d'après des expériences nombreuses, de 7 mètres cubes par heure, et comme les mineurs ont chacun une lampe, qu'il y a en outre des lampes suspendues dans les galeries, on peut estimer à 120 le nombre des lampes allumées, exigeant un volume d'air de. . . . . . . 840

Un atelier de mineurs, de l'importance de celui que nous considérons, exige au moins 6 chevaux consommant ou détériorant chacun de 25 à 30 cubes d'air par heure, ce qui nécessitera encore un cube de. . . . . . . . . . . . . . . . . . . . . . 180

Il faudra encore, pour cet atelier de 100 hommes, environ

*A reporter*. . . . . . 2,220

*Report.* . . . . . 2,220

5 mètres cubes d'air par homme et 15 mètres cubes par cheval pour enlever les miasmes et les produits de la décomposition des matières excrémentielles qui restent forcément dans la mine, soit pour cet article un cube par heure de. . . . . . . . . . . . 590

2,810$^{mc}$

Le volume d'air à renouveler, pour les causes de viciation que nous venons d'énumérer, est donc de 2,810 mètres cubes par heure ou de 0$^{m}$,78 par seconde. Dans ce cas, la quantité d'acide carbonique peut être maintenue entre 2 à 2 1/2 pour mille, c'est-à-dire ne peut avoir d'influence fâcheuse sous le rapport hygiénique.

Pour les gaz produits par la mine elle-même, le volume varie beaucoup d'une mine à l'autre, comme nous l'avons déjà dit; mais dans une même mine le volume est à peu près proportionnel à la surface développée des galeries; aussi plus ces galeries ont de grandes longueurs et plus le volume de ces gaz est considérable. D'après un très-grand nombre d'observations faites dans les mines de *charbon à grisou*, on a reconnu qu'il était nécessaire, pour bien aérer les galeries, que le volume d'air introduit fût compris entre une fois le volume nécessaire à la respiration des ouvriers et quatre fois ce même volume, c'est-à-dire que suivant la nature du combustible de la mine, il était nécessaire pour obtenir l'entraînement des gaz formés naturellement, de donner de 2,800 à 11,200 mètres cubes d'air pur par heure, soit de 0$^{m}$,78 à 3$^{m}$,12 par seconde.

On peut donc supposer que pour bien aérer un atelier de 100 ouvriers mineurs, il faudra introduire et faire circuler dans toutes les galeries de 1$^{m}$,60 à 4 mètres cubes d'air pur par seconde, et comme il vaut mieux pécher dans ce cas par excès de prudence, nous pensons que c'est ce volume de 4 mètres qu'on doit prendre pour base.

Nous croyons que les calculs qui précèdent donnent un volume d'air plus que suffisant dans la plupart des cas; mais dans des mines exceptionnelles dégageant une très-grande quantité de gaz, on pourra augmenter le volume. Nous ne prenons donc ce volume d'air de 4 mètres que comme base pour établir la comparaison entre les divers systèmes de ventilation.

## DES MOYENS ACTUELLEMENT EMPLOYÉS POUR LA VENTILATION DES GALERIES DE MINES.

Pour aérer les galeries des mines, on emploie actuellement un grand nombre de moyens; mais ils peuvent se classer en trois systèmes généraux que nous allons décrire succinctement :

Le premier est celui de la ventilation naturelle, aidée au besoin par un foyer de chaleur;

Le deuxième, celui de la ventilation par insufflation;
Le troisième, celui de la ventilation par aspiration.

Dans toutes les mines, il y a au moins deux puits pour atteindre les couches de minerai à extraire : par l'un de ces puits on fait sortir les produits extraits et l'on introduit aussi les matériaux nécessaires à l'exploitation de la mine, comme bois pour les blindages, etc. Dans le second, on dispose les moyens d'introduction dans la mine des ouvriers et leur sortie, soit en posant des échelles, des escaliers, soit encore à l'aide de procédés mécaniques, mus par des chevaux ou par une machine à vapeur. Beaucoup de mines ont en outre d'autres puits servant à l'épuisement des eaux, ou à l'extraction des produits.

Comme la température de l'air des galeries est toujours plus considérable que celle de l'air extérieur, il se forme un courant ascendant dans l'un des puits, courant qne l'on favorise en chauffant l'air de ce puits : l'air des galeries tend à se diriger naturellement vers ce point de sortie, il est renouvelé par l'air qui s'introduit par les autres puits et l'on aperçoit un courant d'air dans les galeries. Cette ventilation est peu active, surtout en été, où la différence de température entre l'air des galeries et l'air extérieur est peu considérable ; pour l'obtenir énergique, il faudrait chauffer beaucoup l'air du puits d'évacuation, ce qui rendrait son service impossible. Ce moyen de ventilation naturelle, aidé par la chaleur, a été reconnu insuffisant pour la plupart des mines, et il n'est employé seul que dans un petit nombre de cas.

La ventilation par insufflation se fait par des ventilateurs mécaniques, à force centrifuge ou à hélice, ou par des trompes lorsqu'on rencontre un cours d'eau près de l'orifice du puits. L'air est envoyé par le puits d'extraction dans les galeries, il suit ces galeries pour arriver dans les chantiers, puis il ressort par le puits destiné à la rentrée des ouvriers. Comme on peut disposer d'une force assez considérable sur le point où est installé le ventilateur, on peut, par ce moyen, envoyer dans les galeries la quantité d'air nécessaire à une bonne aération; car il suffit, pour augmenter la vitesse du courant dans les galeries, et par suite le volume d'air insufflé, d'employer une force plus considérable en imprimant aux ventilateurs une vitesse de rotation plus grande, ou bien encore en augmentant le diamètre de ces ventilateurs.

Le troisième moyen de ventilation consiste à installer sur le puits de sortie de l'air des galeries des pompes d'aspiration, ou des ventilateurs aspirant l'air du puits. Dans ce cas, la dépression produite dans le puits attire l'air des galeries, il se forme un courant correspondant au degré de dépression produit dans le puits, et l'air des galeries renouvelé par les autres puits de la mine est rejeté dans l'atmosphère.

Ces trois systèmes ont donc l'avantage de renouveler l'air des mines, mais nous pensons qu'ils ne remplissent pas complétement le but qu'on se propose, et notre opinion à cet égard est malheureusement confirmée

trop souvent par les catastrophes funestes qui arrivent dans les mines et qui se terminent par tant de morts ou de blessés.

Il ne suffit pas, en effet, de renouveler l'air respirable des mines; il faut encore expulser des galeries les gaz délétères et les gaz combustibles qui produisent les détonations, et comme ces gaz, suivant leur densité, se logent dans les parties supérieures ou inférieures des galeries, il est nécessaire, pour opérer leur diffusion, d'avoir un courant très-actif dans les galeries, ce qui exigerait une masse d'air considérable et de beaucoup supérieure à celle nécessaire pour le renouvellement de l'air. Les galeries des mines ont des sections bien différentes, elles varient entre $2^m,50$ et 7 mètres carrés : pour opérer un renouvellement complet de l'air et pour donner 4 mètres cubes par seconde, comme nous l'avons indiqué plus haut, il suffit d'obtenir une vitesse de $1^m,60$ à $0^m,60$ par seconde, c'est-à-dire très-faible. Cette vitesse est insuffisante pour produire la diffusion de tous les gaz qui se trouvent dans les plafonds supérieurs et inférieurs des galeries, d'autant plus qu'ils sont retenus en grande partie, comme nous l'avons déjà dit, par les saillies des bois formant les blindages.

Il y a encore une autre cause (et elle est majeure) qui isole la masse des gaz du courant formé dans les galeries. On sait, en effet, que les galeries suivent toujours l'inclinaison si variable des couches à exploiter, et que les directions de ces couches sont loin d'être uniformes; il en résulte que le profil longitudinal des galeries est tourmenté, qu'il présente des parties concaves et des parties convexes, comme le représente la figure 1 ci-jointe. (On a exagéré, ainsi que cela se fait ordinairement, l'échelle des hauteurs.) Sur cette coupe d'une galerie, nous avons indiqué la forme probable du courant d'air par une légère teinte bleue : cette forme ne peut guère varier, car l'air, comme tous les fluides en général, tend à suivre dans sa marche une ligne droite, et ce n'est qu'en rencontrant un obstacle qu'il opère une déviation dans sa direction. On remarquera dans ce profil que sur certains points et toujours dans les parties où la galerie présente un soulèvement ou un abaissement, la colonne d'air subit une diminution de hauteur aux points E E E, et par suite sur ces points la vitesse doit être plus grande pour obtenir le même débit; du reste cette observation a été constatée par les personnes qui fréquentent les galeries de mines : elles ressentent sur certains points des courants qu'elles n'avaient point remarqués sur d'autres. Cela tient d'une part, comme nous venons de le dire, à la différence de hauteur de la colonne d'air et aussi à des étranglements des galeries qui sont loin, comme on le sait, de présenter sur tout leur parcours des largeurs uniformes.

Dans le cas indiqué par la figure 1, et c'est, je crois, le plus général, il se forme dans le plafond inférieur des parties indiquées par les lettres A et B (hachées en noir) qui ne reçoivent point l'effet du courant, et comme ces parties sont, par leur disposition même, celles où les gaz dé-

létères, plus lourds que l'air, doivent se déposer, il en résulte que la diffusion n'a point lieu ou s'opère avec beaucoup de difficulté dans les concavités B B un peu considérables, tandis que cette diffusion peut s'obtenir dans les concavités AA moins profondes.

Le même phénomène se présente dans les parties supérieures des galeries pour les gaz plus légers que l'air; il se forme des espaces CC et DD hachés ou rouge qui se trouvent en dehors du courant, ce qui empêche la diffusion de ces gaz pour les concavités considérables DD, tandis que celles C C peuvent être vidées par le principe d'entraînement.

Ainsi que nous l'avons déja dit, il y a encore d'autres causes qui empêchent la diffusion de ces gaz : d'une part, ce sont les chapeaux qui soutiennent les blindages, en formant entre eux des espaces à l'abri des courants, et d'autre part ce sont les éboulements assez nombreux qui ont lieu dans les plafonds supérieurs des galeries. Ces éboulements forment des poches, comme celle indiquée en H sur le profil n° 1. Ces excavations se remplissent de gaz, et le courant d'air de la galerie est dans l'impossibilité de les vider parce que l'action de la diffusion est trop éloignée.

Pour remédier à ces graves inconvénients, on place bien de distance en distance, sur les points où il y a des poches, des cloisons mobiles, comme celle indiquée par RS sur le profil n° 1, de manière que le courant d'air est obligé de lécher la partie supérieure de la galerie, mais ces cloisons ont un grand nombre d'inconvénients. D'abord elles gênent la circulation dans les galeries, et par suite les ouvriers ne les placent que lorsqu'ils ne peuvent faire autrement et souvent lorsque l'air supérieur est déja inflammable; puis elles gênent beaucoup la circulation de l'air en lui présentant des obstacles, de sorte que la vitesse de cet air est ralentie dans les galeries.

Il résulte de ces effets physiques que, sur certains points inférieurs des galeries, les gaz délétères ne sont point entraînés et que dans les plafonds supérieurs et dans les poches, il reste encore une grande quantité de gaz combustibles qui, à un moment donné, par une cause accidentelle produite souvent par l'imprudence proverbiale des ouvriers, font des explosions.

On pourrait bien, par une ventilation plus active, c'est-à-dire en produisant dans les galeries une vitesse plus grande, augmenter beaucoup la diffusion et opérer le mélange d'une plus grande quantité de gaz avec l'air des galeries; mais dans ce cas il faudrait employer une force beaucoup plus grande, car l'on sait que la force nécessaire est proportionnelle au carré des vitesses. Je crois, en outre, qu'on ne pourrait arriver à un mélange complet des gaz combustibles, parce qu'ils ont, par leur densité, très-peu de tendance à se mêler avec l'air, et puis aussi parce qu'ils se logent dans des cavités trop isolées du courant.

Nous ne parlerons point des résistances nombreuses que l'air éprouve

pour circuler dans les galeries par suite des aspérités des parois, des étranglements et des coudes brusques que les galeries forment entre elles, et l'on sait combien ces coudes sont nombreux dans une mine exploitée par galeries, présentant une très-grande longueur sur une petite surface. Aussi, pour que l'aérage des galeries soit complet, il faut presque toujours avoir des portes pour fermer les issues directes et pour forcer l'air de suivre toutes les sinuosités des galeries, soit en projection horizontale, soit en projection verticale; ces causes de diminution de la vitesse du courant d'air sont les mêmes dans tous les cas, et doivent être combattues par un excédant de puissance des ventilateurs et, par suite, par une plus grande consommation de houille.

Nous ferons seulement remarquer que dans le cas d'accident, si des éboulements viennent à isoler les chantiers des puits d'aérage, les ouvriers sont livrés à une mort certaine par asphyxie, si l'on ne peut enlever rapidement ces éboulements et pénétrer jusqu'à eux avant qu'ils aient consommé et rendu irrespirable le petit volume de l'air de leur prison, et l'on peut presque dire de leur tombeau.

DE LA VENTILATION PAR L'AIR COMPRIMÉ. Pour remédier aux inconvénients que nous venons de signaler d'une manière générale et pour rendre plus efficace et plus complète la ventilation des mines, nous avons la conviction que l'emploi du système de la ventilation par l'air comprimé peut être employé avec beaucoup d'avantage. Nous allons indiquer les dispositions générales qu'il conviendrait d'adopter pour l'emploi de ce système, et aussi faire ressortir les avantages qu'on pourrait en retirer.

Deux puits d'aérage sont nécessaires, comme dans les autres systèmes de ventilation : l'un pour la rentrée de l'air pur, l'autre pour la sortie de l'air vicié et des gaz qui se forment dans les galeries. Un tube en fer d'un diamètre variable, selon l'importance de la mine, partirait du sommet du puits où se ferait la rentrée de l'air, descendrait jusqu'au niveau des galeries à ventiler, suivrait le cours des galeries principales, irait jusqu'aux chantiers de travail des ouvriers, puis il reviendrait ensuite par les galeries qui conduisent au puits de sortie de l'air et se terminerait à l'orifice supérieur de ce puits. Sur ce tube principal viendraient s'embrancher d'autres tubes, de diamètres plus petits, qui suivraient les galeries secondaires, de manière que le réseau des galeries puisse recevoir, sur tous les points, un jet d'air comprimé.

A l'aide d'une partie de la force de la machine à vapeur placée près du puits de rentrée de l'air et d'une pompe de compression, on refoulerait de l'air comprimé dans toute la longueur de ces tubes, à une pression qu'on calculera suivant l'importance de la mine, et par suite suivant la quantité d'air comprimé qu'on devrait employer pour maintenir à peu près constante la pression dans toute la longueur de la conduite.

Dans le puits d'entrée de l'air, à l'aide d'une tubulure sur le tube de conduite de l'air comprimé, on dirigera un jet moteur dans le sens de la profondeur. Par suite du principe d'entraînement, l'air extérieur se précipitera dans le puits, et l'on obtiendra ainsi une rentrée d'air pur d'un volume déterminé, puisque, ainsi que cela vous a été expliqué par M. de Mondesir dans la dernière séance, il suffit de faire varier la pression où le diamètre de sortie de l'air pour produire une vitesse déterminée suivant le diamètre du puits.

Remarquons tout d'abord que ce premier jet remplace les ventilateurs mécaniques, et que probablement, avec une force moindre, on obtiendra les mêmes résultats qu'avec les ventilateurs les mieux établis.

Comme l'air dans sa marche éprouve des résistances par le frottement sur les parois, et que dans les galeries ces résistances sont fort grandes par suite des aspérités, des coudes et aussi par les objets encombrants dont elles sont si souvent embarrassées, on peut, suivant l'état de ces galeries, compenser ces frottements par de petits jets supplémentaires d'air comprimé, établis de distance en distance et principalement sur les points où il y a des étranglements dans les galeries et sur ceux où ces galeries forment des coudes très-brusques. Ces jets supplémentaires peuvent être considérés comme des renforts, et l'on pourra avec leur aide maintenir un vitesse constante dans toute la longueur des galeries. Ce résultat immense ne peut être obtenu par le système de ventilateurs mécaniques, puisqu'aucune force supplémentaire, aucun renfort, ne peut venir compenser la perte de charge si grande due aux frottements.

L'établissement de ces jets supplémentaires sera facile, puisqu'il suffira de poser des tubulures sur les tubes de conduite de l'air comprimé pour en faire sortir un jet qu'on pourra calculer suivant les besoins, et qui d'ailleurs sera toujours très-peu considérable.

Un échappement d'air comprimé serait également établi près des chantiers d'abattage, afin de maintenir sur ce point le courant d'air très-actif, et aussi pour produire un mélange complet de l'air entraîné avec les gaz développés, dans cette partie, en plus grande abondance que sur les autres.

Un ou plusieurs jets supplémentaires d'air comprimé seraient aussi établis dans la galerie qui conduit au puits de sortie de l'air; enfin un dernier jet serait lancé dans le puits de sortie de l'air et dans le sens de cette sortie, afin de faciliter l'évacuation de l'air des galeries et des gaz qui se seront mélangés avec lui, soit par le principe de l'entraînement, soit par celui de la diffusion.

On remarquera que ce mode de ventilation se trouve complétement dans le même sens que la ventilation naturelle produite par la différence des températures de l'air des galeries et de l'air extérieur, et qu'il facilite cette ventilation naturelle : on remarquera également que ce nouveau système a les avantages du mode d'insufflation et du mode d'aspira-

tion ; aussi nous avons la conviction qu'il doit être très-énergique et que la ventilation doit être complète.

Dans la description générale que nous avons faite précédemment des systèmes employés pour les galeries de mines, nous avons fait remarquer que les gaz délétères et les gaz combustibles, suivant leur densité, se logent dans les concavités produites par le profil des galeries, et dans les poches formées soit par les éboulements des plafonds, soit par les vides entre les bois des blindages ; et dans la figure 1, nous avons indiqué la forme probable du courant de ventilation, qui laisse en dehors de son action les cavités B remplies de gaz délétères, et celles D D contenant des gaz combustibles pouvant produire des détonations. Avec l'emploi du système que nous proposons, le mélange des gaz de ces cavités avec l'air de la galerie peut être facilement opéré. Dans la figure 2 nous avons pris le même profil que celui de la figure 1, et nous avons indiqué aussi la forme probable et approximative du courant d'air dans les galeries, lorsque la ventilation s'opérera, soit par un système, soit par l'autre. Dans cette figure 2 nous avons tracé en bleu le tube de conduite d'air comprimé sur l'une des parois du puits d'aérage et dans le sol de la galerie, pour qu'il ne puisse gêner la circulation. Nous avons indiqué, dans le puits d'entrée de l'air, le jet d'air comprimé moteur qui procure l'entraînement du volume d'air nécessaire à l'aération complète des galeries. Au point *m* nous avons placé un jet supplémentaire ou de renfort pris par une tubulure *n* sur le tube de conduite de l'air comprimé (ce jet a pour but, ainsi que nous l'avons dit, de maintenir la même vitesse de l'air dans toute la longueur des galeries, c'est-à-dire qu'il a pour résultat de compenser les pertes de charge produites par les frottements de l'air sur les parois des galeries). Pour produire la diffusion ou l'entraînement des gaz détonnants dans la concavité D, qui se trouve par sa disposition en dehors du courant, nous pensons qu'il conviendrait d'établir une cloison en planches, isolant complétement cet espace D de la galerie, et de laisser aux deux extrémités des ouvertures pour la rentrée de l'air ou la sortie des gaz ; on établirait alors en P une tubulure sur le tube de conduite d'air comprimé, et par un petit tube placé le long d'une des parois de la galerie on ferait une injection en O, à l'entrée de la gaîne ; l'air de la galerie serait attiré suivant la flèche du profil : il formerait un courant actif, entraînerait tous les gaz et les rejetterait dans la galerie au point R, dans le courant général, après avoir opéré la diffusion complète des gaz renfermés, soit dans cette gaîne, soit dans les poches du plafond.

Il serait établi également dans les cavités inférieures, comme on l'a indiqué en B, des gaînes et des jets d'air comprimé O′, pour entraîner les gaz délétères qui se déposent dans la partie inférieure et qui ne peuvent opérer leur diffusion dans l'air de la galerie, parce qu'ils sont trop en dehors du courant général.

Avec l'adoption du système de ventilation par l'air comprimé, avec les précautions peu coûteuses que nous venons d'indiquer, avec la division si facile de la force motrice de l'air comprimé et son emploi sur les points des galeries où il serait nécessaire de l'employer on pourrait opérer une ventilation complète; on pourrait obtenir la diffusion complète de tous les gaz formés dans les galeries, et les chasser en dehors de la mine, et, par suite, éviter tous les sinistres qu'on a trop souvent à enregistrer dans les sombres annales des mines.

Le système que nous proposons de la ventilation par l'air comprimé aurait sans doute besoin de plus grands développements, mais nous n'avons point voulu fatiguer trop longtemps votre attention, et nous avons cru devoir nous borner à une description générale de notre système, pour en faire comprendre les avantages.

Nous croyons cependant utile de dire encore qu'en cas de catastrophe dans une mine, dans celui où des éboulements viendraient à se produire dans les galeries, les ouvriers qui se trouveraient renfermés dans un espace presque toujours très-restreint, entre deux éboulements, pourraient cependant, par le moyen de la conduite principale d'air comprimé ou des tubes d'embranchement qui parcourent toutes les galeries, recevoir l'air nécessaire à leur respiration. Par ces conduites servant de tuyaux d'acoustique on pourrait communiquer avec les ouvriers, et même on pourrait leur transmettre des aliments liquides confortatifs. Cet avantage serait immense, et réuni à ceux que nous avons déjà énuméré, il donnerait une sécurité qu'on ne rencontre point dans les autres systèmes de ventilation; il arracherait à une mort presque certaine un très-grand nombre d'ouvriers qui périssent par asphyxie, enfin il diminuerait, dans une notable proportion, les dépenses causées aux propriétaires des mines dans le cas malheureusement si fréquent de catastrophes.

La dépense annuelle, occasionnée par le système de ventilation que nous venons de vous exposer, pourrait facilement, en faisant varier la pression de l'air moteur, arriver à un taux inférieur à celle nécessaire pour l'emploi des ventilateurs mécaniques. Dans tous les cas, cette dépense ne sera pas supérieure : il resterait donc seulement la dépense première de l'installation, qui ne serait point très-grande, puisqu'elle se bornerait, comme nous l'avons dit, à la pose d'une conduite et d'embranchements dans les galeries, pour l'air comprimé moteur. Cette première dépense une fois faite, et elle serait peu élevée, les avantages qu'on pourrait en retirer nous paraissent tellement nombreux, que les propriétaires des mines ne devraient point, à notre avis, hésiter un seul moment à l'effectuer, parce qu'ils retrouveraient une valeur bien plus grande, en évitant les accidents et leurs terribles conséquences, et en rendant plus commode l'exploitation de leurs mines.

Pour produire un cube d'air de 4 mètres cubes dans les galeries par seconde, chiffre que nous avons déterminé plus haut, et pour l'introduire

par le puits que nous supposerons de 4 mètres carrés, c'est-à-dire d'un diamètre de 2$^m$,25, en employant de l'air comprimé à une atmosphère, il faudrait un jet moteur de 0$^m$,0055, suivant la formule que M. de Mondesir vous a fait connaître dans son exposé de la théorie de la ventilation par l'air comprimé :

$$u = 404 \frac{d}{D} \sqrt{\mu}.$$

Dans ce cas la vitesse $u$ est de 1$^m$,00 par seconde.

Ce jet de 0$^m$,0055 de diamètre, en supposant 286 mètres par seconde pour la vitesse d'échappement de l'air à une atmosphère, exigera un cube d'air comprimé de 6 litres, 89 par seconde ou 24 mètres cubes par heure, correspondant à une force d'un cheval 3/4 vapeur ou à 4$^k$,37 de charbon par heure.

Avec cette force minime on est assuré de la rentrée de 4 mètres cubes d'air dans les galeries de la mine : si l'on ajoute une force double, pour les relais ou renforts qui seraient établis dans les galeries, pour compenser la perte de charge due aux frottements et pour les jets supplémentaires qu'il faudrait établir pour opérer la diffusion des gaz et leur entraînement, on voit qu'avec une force motrice de 5 à 6 chevaux-vapeur, c'est-à-dire avec une consommation de 12$^k$,50 à 15 kilog. de charbon par heure, on pourrait établir la ventilation complète des galeries.

M. de Mondesir vous a expliqué, lorsqu'il vous a parlé des expériences faites au Champ de Mars, sous la direction de M. Tresca, qu'on avait obtenu une rentrée d'air dans les galeries de 13 à 14,000 mètres cubes à la vitesse d'un mètre, par force de cheval-vapeur et par heure, soit environ 4 mètres par seconde. En supposant que pour compenser les frottements de l'air dans les galeries on soit obligé de quintupler cette force, on voit que l'on arriverait à peu près au résultat que nous vous avons signalé plus haut, et qu'avec une force de cinq à six chevaux-vapeur on pourrait ventiler de la manière la plus effective possible les galeries d'une mine[1]; que, par ce moyen, on pourrait donner aux ouvriers tout l'air nécessaire pour leur respiration, mais encore, on produirait la diffusion et l'entraînement de tous les gaz délétères ou combustibles, et que, par suite, on éviterait tous les inconvénients des travaux souterrains, et surtout ceux qui résultent des inflammations des gaz combustibles.

Dans presque toutes les mines de houille, il y a plusieurs bancs à ex-

1. Comme dans les mines de houille le prix du charbon, au carreau de la mine, ne dépasse guère 1 fr. 20 c. p. 100 kil., la dépense du combustible du moteur ne serait que de 18 centimes par heure ou de 4 fr. 30 c. par 24 heures. Pour les autres frais, c'est-à-dire pour le salaire des mécaniciens, chauffeurs, etc., ils sont compris dans la dépense relative à la remonte des produits de la mine, et il n'y a point lieu de les compter dans la dépense de ventilation.

ploiter, placées à des niveaux différents, et par suite plusieurs étages de galeries; on comprend que dans ce cas, presque général, il faudrait établir un système de conduite d'air comprimé pour chacun des étages, pour s'en servir comme nous l'avons expliqué précédemment. Il faudrait alors donner à la conduite maîtresse dans le puits d'introduction de l'air un diamètre plus grand et en rapport avec la dépense calculée de l'air comprimé dans les différents étages de galeries. On donnerait aussi un diamètre plus grand au premier jet moteur, afin de faire entrer dans le puits d'aérage le volume d'air nécessaire à tous les étages des galeries.

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Fig 1.

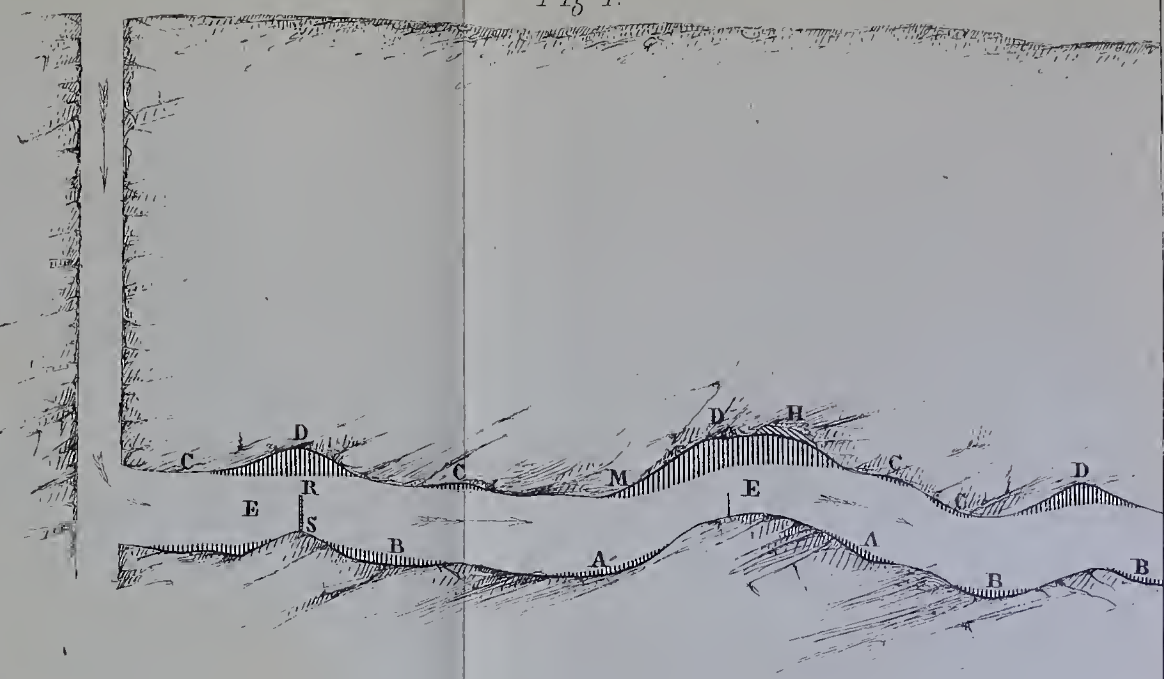
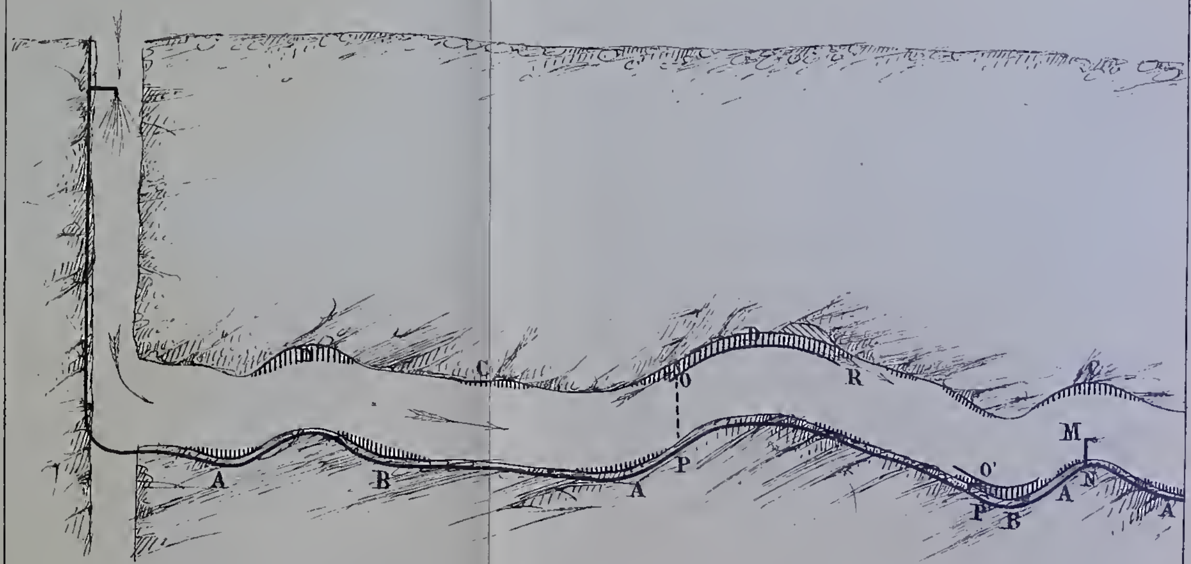



Fig. 2.



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